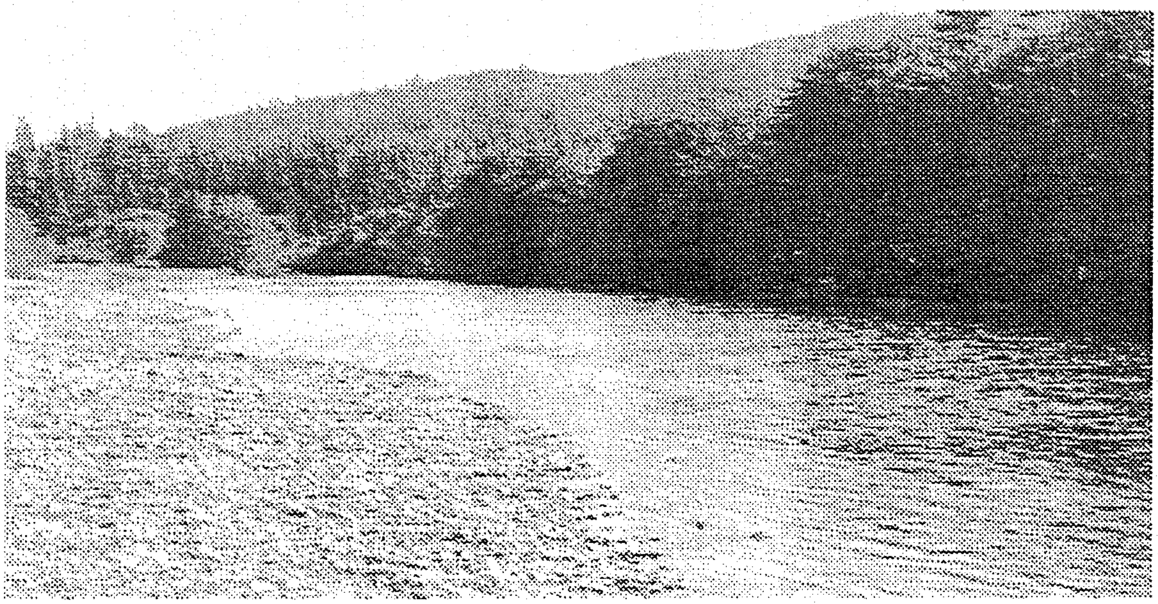
Experimental Comparisons of Fish Habitat and Fish Use Between Channel Rehabilitation Sites and the Vegetation Encroached Channel of the Trinity River



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Cover photograph from: Looking upstream at the Douglas City rehabilitation site.

This Report Should Be Cited as:

Gallagher, S. P. 1999. Experimental comparisons of fish habitat and fish use between channel rehabilitation sites and the vegetation encroached channel of the Trinity River. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, CA. 73 pp.

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ABSTRACT

Bank rehabilitation in the Trinity River was conducted by removing the riparian encroached berm at nine sites between 1989 and 1992. This untested approach to river restoration was intended to increase habitat and habitat diversity with increased and variable flows. An intensive comparison of fish use, fish habitat, and habitat diversity between channel rehabilitation sites and the unrehabilitated channel in the Trinity River was conducted during 1997 and 1998. Four of the nine channel rehabilitation sites were randomly selected and adjacent contemporaneous controls established. During 1997 hydraulic transects, necessary for the collection of data for input into the Physical Habitat Simulation System (PHABSIM), were established at control sites and reestablished at rehabilitation sites. Hydraulic data needed for the calculation of Weighted Usable Area (WUA) were collected at three Lewiston Dam releases (13.9, 32.3, and 60.9 m^3/s). Complete depth and velocity data sets were collected for all transects at all three flows. The WUA for chinook and coho salmon and steelhead fry and juveniles was calculated using river specific species criteria and the actual hydraulic data (not simulated). Fish use was documented by electrofishing 3 by 42 m lanes along both banks of rehabilitation and control sites during April 1997 at a flow of 13.9 m^3/s. Surveying techniques were used to develop scaled grid maps of each site. A micro-habitat delineation system, based on physical features in the river, was developed to map habitat diversity at all sites. During 1997 habitat was mapped at 9.6 and 43.9 m^3/s Lewiston Dam releases at all sites. During 1998 an intensive electrofishing mark recapture program using cold branding techniques to determine young of the year chinook salmon population levels at rehabilitation and control sites was conducted. Two 3 by 42 m lanes were sampled along both banks of rehabilitation and control sites. Fork length and total number of all species captured was recorded. In addition, chinook salmon weights were measured. High flows and storm events limited this sampling to four visits between February and April 1998. Habitat mapping was conducted at all sites for Lewiston Dam releases of 76.5 and 145.8 m^3/s. Habitat unit use (presence or absence) for each habitat type encountered was developed by biologists familiar with the river system. Four replicates of each unit were electrofished during 1998 to verify the use of each unit type by the species and life stages of interest.

Channel rehabilitation sites were significantly wider and shallower than controls as flows increased. The bed, velocity, and depth profiles across the channel were more diverse at rehabilitation sites. These attributes also appear to increase in diversity with increased flows. At higher flows chinook salmon and steelhead fry WUA is significantly greater at rehabilitation sites. At lower flows there is more steelhead juvenile WUA at control sites. Calculated WUA between rehabilitation and control sites trends moved towards non-significantly more WUA at rehabilitation sites as flows increase, such that at 42.3 m^3/s all species and life stages examined show more WUA at rehabilitation sites. Coho salmon WUA did not significantly differ between treatments at any flow. The effect of rehabilitation on fry and juvenile salmon habitat is an overall increase in WUA. Fish density indices at 13.9 m^3/s during 1997 were not significantly different between treatments, except for steelhead fry which were more abundant at rehabilitation sites. However, fish density patterns mirrored WUA patterns for the 13.9 m^3/s discharge. There were more chinook salmon and steelhead fry at rehabilitation sites and more juveniles at control

sites. This is likely a result of differences in velocities between the sites as juveniles use higher velocities. Fish catch per unit effort during 1998 followed trends observed during 1997 for total capture and WUA at 13.9 m^3/s. More fry were captured at rehabilitation sites and more juveniles at control sites. The differences were significant for chinook salmon fry.

Although the recapture rate during the 1998 freeze branding study was low (0.63%), we documented chinook salmon rearing in the Trinity River for at least 49 days. Fish were recaptured in the same 3 x 42 m area along the bank at both rehabilitation and control sites despite large changes in flow (13.9 to 79 to 43 m^3/s) during the study. The mark recapture efficiency was affected by unanticipated high flows and storm events during 1998. However, the catch per unit effort and length-weight data collected concurrently with the cold branding study proved quite useful for examining catch per unit effort between treatments.

Fish species diversity was not significantly different between rehabilitation and control sites. When the data from the rehabilitation and control sites were pooled (to create an *existing channel data set*) and compared to control site data, no difference in fish species diversity was found. Similarly, there was no difference in habitat diversity between treatments at any of the four flows for which'habitats were mapped. However, when existing channel habitat diversity was compared to control site diversity a significant increase as a result of rehabilitation was shown for fry habitat diversity as flows increase. The existing channel versus control site diversity comparisons by species and life stage for chinook and coho salmon and steelhead show more diverse habitat with increasing flows. Chinook salmon fry were significantly smaller and juveniles were larger at rehabilitation sites during 1998 suggesting more habitat diversity (wider niche breadth) at these sites. These observations coupled with bed, velocity, and depth profile diversity increases, especially with increased flow, and significant increases in WUA lend evidence to the idea that channel rehabilitation in the Trinity River has increased diversity. By coupling rehabilitation to variable flows it may be possible to more closely mimic the complex and diverse habitat conditions and habitat mosaics these species evolved under. Increased watershed and stream rehabilitation along with long term adaptive management monitoring including development and testing of specific hypotheses will be necessary to determine the ultimate benefits of this type of rehabilitation to salmonid populations.

INTRODUCTION

The extensive ecological degradation caused by damming rivers and the resultant flow regulation is well documented (Ward et al. 1995, Stanford et al. 1996, Poff et al. 1997, Richter et al. 1997). All large rivers in the northern third of the world are regulated (Dyneius and Nilsson 1994). The most important factor contributing to loss of aquatic biodiversity is habitat loss or degradation (Miller et al. 1989). Damming rivers and flow regulation causes a loss of habitat and biodiversity and lowers bio-production (Richter et al. 1996, Stanford et al. 1996) by dampening large scale natural hydrologic variability which drives habitat maintenance processes (i.e. geomorphology, Ligon et al. 1995), habitat heterogeneity (Gorman and Karr 1978, Gregory et al. 1991), ecological connectivity (Stanford et al. 1996), successional patterns (Ward and Stanford 1995), and ultimately compromises ecosystem integrity (Poff et al. 1997, Richter et al. 1997). Riparian components of river ecosystems are also negatively effected by dams (Rood and Heinze-Milne 1989, Auble et al. 1994, Rood et al. 1995, Nilsson et al. 1997) which further compromises ecosystem integrity.

The Trinity River has experienced a decline in Pacific salmon (*Oncorhynchus sp.*) and steelhead (*O. mykiss*) as well as large scale changes in riparian communities (Evans 1979, USFWS 1990, 1994, McBain and Trush 1997). The key factor is the Trinity River Division of the Central Valley Project- Trinity and Lewiston Darns. This project diverts up to 90% of the Trinity River's annual discharge and blocks access to 175 km of spawning and rearing habitat. Reduced and stabilized flows that followed construction of the Trinity River Division allowed the establishment of riparian vegetation (Evans 1979, Wilson 1993) which encouraged berm formation, eliminated lateral recruitment of new gravels, and reduced salmonid spawning and rearing habitat (USFWS 1994).

Public Law 98-541 of 1984 authorized a ten year restoration effort of fish and wildlife resources in the Trinity River basin. This law was re-authorized for an additional 3 years in 199.5. In 1988 the Trinity River Restoration Program (TRRP) began fishery habitat enhancement by building artificial side channels and modifying banks on the main stem Trinity River to improve rearing conditions for young of the year salmonids (CH2MHILL 1994, USFWS 1988, 1994, 1997). Between 1988 and 1993 the TRRP built 18 side channels and modified the banks (channel rehabilitation sites or feathered edges here after referred to as rehabilitation sites) at nine sites along the main stem Trinity between Lewiston Dam and the North Fork Trinity River. The USFWS (1994) recommended rehabilitation to reverse the decline in chinook salmon rearing habitat associated with increasing flows from 8.4 to 28.3 m^3/s. Rehabilitation was intended as a means of restoring river bars to their historic configuration and providing increased rearing habitat with increased flow (USFWS 1994). McBain and Trush (1997) suggested that rehabilitation and increased flows will assist in attainment of their ten attributes of a healthy river. They state that alternate bars at one rehabilitation site already provide more diverse habitat between flows of 8.4 to 169.9 m^3/s. The USFWS (1994), citing an unpublished report, stated that chinook fry habitat increased by 6.7% and juvenile habitat increased by a factor of 2.3 as a result of rehabilitation, Gallagher (1995), due to insufficient pm-project information on the rehabilitation sites for comparison to post project evaluations, compared fish use and weighted usable area (WUA) between the feathered (here after referred to as constructed) bank and the unaltered (here after referred to as unmodified) bank. Results indicated no significant differences in fish density and WUA between constructed and unmodified banks at the nine rehabilitation sites.

River restoration is a common practice but is rarely subject to post project evaluation (Kondolf 1995, Kondolf and Micheli 1995, Kondolf et al. 1996). The few rehabilitation projects that have been subjected to post project review have failed (Frissell and Nawa 1992) or contributed little to the improvement of streams (Iversen et al. 1993). Anadromous salmonid rehabilitation has relied on technological solutions such as hatcheries, fish ladders and in-stream manipulations (Bottom 1997). The failure of hatcheries (Meffe 1992) and stream manipulations, especially concerning single species management, has recently been recognized and the focus of rehabilitation is currently shifting towards ecosystemrestoration (National Research Council 1996, Standford et al. 1996, Kauffman et al. 1997) using hydrologic variability (Ligion et al. 1995, Ward and Stanford 1995, Richter et al. 1996, Poff at al. 1997, Richter at al. 1997). Hill and Platts (1998) used varied stream flows (passive rehabilitation) to reestablish complex and productive habitat in the Owens River, California.

The purpose of this study was an intensive post-project evaluation of fish use and fish habitat at channel rehabilitation sites on the Trinity River. Contemporaneous controls were established to compare fish habitat and use between rehabilitation sites and the unrestored channel. Specific hypotheses were (1) fish habitat is not more diverse as a result of rehabilitation,(2) fish habitat and fish biomass are not increased by rehabilitation, (3) fish use has not increased as a result of rehabilitation. Information assisting in the connection between habitat diversity (ie. geomorphic attributes) and fish diversity, density, and bio-production is provided.

STUDY AREA

Description

The Trinity River watershed drains approximately 7,679 km’ in Trinity and Humboldt Counties in northwestern California. It is a major tributary of the Klamath River and has historically supported large runs of chinook salmon and steelhead (Moffet and Smith 1950). Lewiston Dam at river kilometer (rkm) 180 marks the upstream limit to salmon and steelhead migrations. The upper segment of the river from Lewiston Dam to the North Fork Trinity River confluence is the most important for salmonid production (USFWS 1988). This segment is characterized by a generally narrow channel with steep, heavily vegetated banks. The stream gradient is relatively high and the river bed is composed of sand, gravel, and cobbles.

Fish Species

The Trinity River supports native populations of speckled dace *(Rhinichthys osculus)*, Pacific Lamprey *(Lampetra tridentata)*, chinook salmon (*Oncorhynchus tshawytscha)*, coho salmon (0. *kisutch)*, Klamath sucker *(Catostomus rimiculus)*, steelhead and resident rainbow trout, and green sturgeon *(Acipenser medirostris)*, as well as non-native three spine sticklebacks *(Gasterosteus aculeatus)* and brown trout *(Salmo trutta)*. Other non-native fish species found in the river, which may not have reproducing populations, include green sunfish (*Lepomis cyanellus*) and brown bullhead (*Ameiurus nebulosus*). Klamath lamprey *(L. similis)* have been observed in Weaver Creek, a tributary to the Trinity, and may be present in the mainstem Trinity. Historically, the Trinity River supported spring-, summer-, and fall-run chinook salmon (Moffet and Smith, 1950). The fall-run is now the largest. Fall-run spawning occurs between September and December. Fry emergence occurs from late January through May. Juvenile rearing occurs from February through July with some fish rearing until September or October (CH2MHILL 1994). The main out-migration of juvenile chinook salmon begins in March, peaks in May and June, and ends by July (P. Zedonis, Personal Communication). A second out-migration has been observed to occur in the fall.

STUDY SITES

Rehabilitation Sites

Four of the nine rehabilitation sites were randomly selected (Appendix A) for collection of habitat diversity, fish density/use data, and the physical hydraulic data necessary to calculate habitat indices in order to address the hypotheses described above. The sites selected were Bucktail (BKT), Lime Kiln (LMK), Steiner Flat/Douglas City (DGC), and Bell Gulch (BLG) (Table 1).

Control Sites

For each rehabilitation site a contemporaneous control site was selected. Each control was set in the same reach as the rehabilitation site, was intended to be the same size and have the same number of hydraulic transects. The upstream end of each control sites was set a minimum of 43 m (approximately 1 channel width) from the downstream end of the rehabilitation site. The BKT, LMK, and BLG control sites were established downstream of and in proximity to the rehabilitation sites. The DGC control site was established upstream of the rehabilitation site (Table 1). Because it was necessary for each control site to be as similar as possible to its' corresponding rehabilitation site it was difficult to find areas in the river of exactly the same length that had similar gradient and depth. Therefore, the control sites are not the same length as the rehabilitation sites and only two transects were established at the BKT control (Table 1).

MATERIALS and METHODS

Physical Habitat

During 1997, hydraulic data transects were established at all control sites and transects at rehabilitation sites (Gallagher 1995) were relocated. Physical habitat data (hydraulic and structural) were collected at both rehabilitation and control site transects for input into the Physical Habitat Simulation System (PHABSIM) following procedures outlined in Trihey and Wegner (198 1) and Bovee (1994). Data included were: 1) water surface elevations; 2) bed elevations; and 3) mean column water velocities. Substrate data were not collected (USFWS 1995, 1997). Hydraulic data were collected at all sites for Lewiston Dam releases of 13.9, 32.3, and 60.9 m^3/s. Complete velocity data sets were collected for all transects at all three flows.

Table 1. Site name, distance from Klamath confluence, length of river represented, and number of transects for four rehabilitation and control sites on the Trinity River.

Site Name	Location (rkm)	Length (m)	Number of Transects
Bucktail Rehabilitation	169.7	120.4	3
Bucktail Control	169.4	88.4	2
Lime Kiln Rehabilitation	161.2	213.4	3
Lime Kiln Control	160.7	158.5	3
Douglas City Control	149.2	204.2	5
Douglas City Rehabilitation	147.9	320.3	8
Bell Gulch Rehabilitation	135.5	198.1	3
Bell Gulch Control	135.3	167.6	3

Habitat suitability criteria (HSC or SI curves) are used within PHABSIM to translate hydraulic and structural elements of rivers into indices of habitat known as weighted usable area or WUA (Bovee 1996). Equation 1 and the river specific HSC (Equation 2, Fig. 1) from Hampton

(1988) were used to calculate WUA for chinook and coho salmon and steelhead fry (< 50 mm) and juveniles (> 50 mm). The first step of this calculation was determination of depth and velocity HSC for each species and life stage for all cells across each transect at all three flows. In order to avoid the assumptions and calibration problems associated with the hydraulic models in PHABSIM (Railsback 1999), I used data base modeling to directly determine HSC from the field data for each cell. The WUA for each cell was then calculated and summed across transects to produce habitat indices. Transects were weighted equally.

Equation (1) (from Bovee 1996)

Weighted Usable Area $WUA_{Q,S} = \Sigma (a_{i,Q}) (CSI_{i,Q,s})$

Q = River Discharge

S = Species and Life Stage

$a_{i,Q}$ = Surface Area of Cell I at Flow Q

$CSI_{i,Q,s}$ = Composite Suitability of Cell (I) at Flow (Q) for Species and Life Stage (S)

Equation (2) From Bovee (1996)

$CSI = (SI_d) (SI_v) (SI_c)$

SI_d = Suitability Index for the Depth of the Cell

SI_v = Suitability Index for the Velocity of the Cell

SI_c = Suitability Index for the Cover or Channel Index of the Cell

Habitat Diversity

To examine differences in habitat diversity between rehabilitation and control sites a habitat classification system based on physical characteristics of the river which reflects habitats used by the species and life stages of fish found in the Trinity River was developed (Glase In Prep.). The habitat types are those found in the Trinity River at rehabilitation and control sites and are mainly habitats found along the river edge. The habitat typing followed techniques of Rosgen (1996) and Flosi et al. (1998) but were modified to encompass supra-micro habitats along the river's edge (Glase In Prep.).

Habitat mapping was conducted by two to six trained biologists using the following procedure: Planform maps showing transects, wetted edges, and having a 3.1 m^2 grid overlay were created by surveying each site and were used to draw in habitats. Measuring tapes were strung across the river along existing hydraulic transects and used to estimate distances. The wetted edge of each transect on each bank was recorded on the maps for each flow. Each biologist was assigned a river bank or section between tapes. In each section the biologist moved upstream identifying distinct habitats. For each unit the investigator identified the habitat type, the cause, shear zones (defined as a distinct velocity break), and cover types including the percentage of cover in each unit. Using his/her eye, pacing (or a meter tape), and the 3.1 m^2 grid map the biologist delineated onto the map the boundaries of each habitat. This was labeled on the map and delineation descriptors were recorded in note books. Habitat mapping was conducted during four different Lewiston Dam releases ranging from 9.57, 43.9, 76.5, and 145.8 m^3/s. The field maps were traced onto Mylar, scanned into a computer and Arc/Info (Environmental Systems Research Institute, Inc. 1994) was used to calculate total area of each habitat type for each site at each flow. This information was used to compare total habitat diversity between rehabilitation and control sites.

A second focus of the mapping effort was to assign species and life stage use values (presence or absence) to the habitat types. The first approach was to estimate species and life stage presence or absence for each habitat type. This was verified by electro-fishing replicates of each habitat type. Ideally, 30 replicates of each habitat type would be sampled using an equal effort sampling approach in mid-February, in late-March, and in late April. Time and budget constraints and high river flows limited the sampling to one effort during peak rearing time (late-March, 1998) and four replicates of each habitat type. Habitat mapping verification followed a completely randomized design. During 1997 43 unique habitat types represented by 638 units were mapped. Of these, 32 were represented by more than three individual units. To increase the pool of units to be randomly selected I combined some habitats of similar form to get 37 types represented by greater than four units. From these I randomly selected four of each type for sampling of fish use. These units were sampled by equal effort electro-fishing during 1998, The average percent use of habitat types was calculated for all species captured. This data was combined with our estimates of fish use of each habitat type to estimate species and life stage use of each habitat type (Appendix B). Species and life stages not encountered or encountered in low numbers will require further work (ie. summer holding coho and steelhead juveniles or adult spring chinook).

Fish Use

To examine fish use and catch per unit effort differences between rehabilitation and control sites, one set of 42.5 m by 3 m lanes along both banks of all rehabilitation and control sites were electro-fished using a single pass equal effort approach. During 1997 all sites were electro-fished during the week of 7 April. The starting point of each lane was randomly selected based on the hydraulic transects. All fish captured were counted and identified. Chinook and coho salmon, brown trout, and steelhead fork lengths were measured. As a preliminary test of a mark recapture procedure to determine rearing duration and to examine density differences between the constructed bank and the unmodified bank, fish caught by electro-fishing one 42.5 by 3 m lane along each bank at the DGC rehabilitation site were marked and released. This site was sampled four times between 29 April and 8 May 1997.

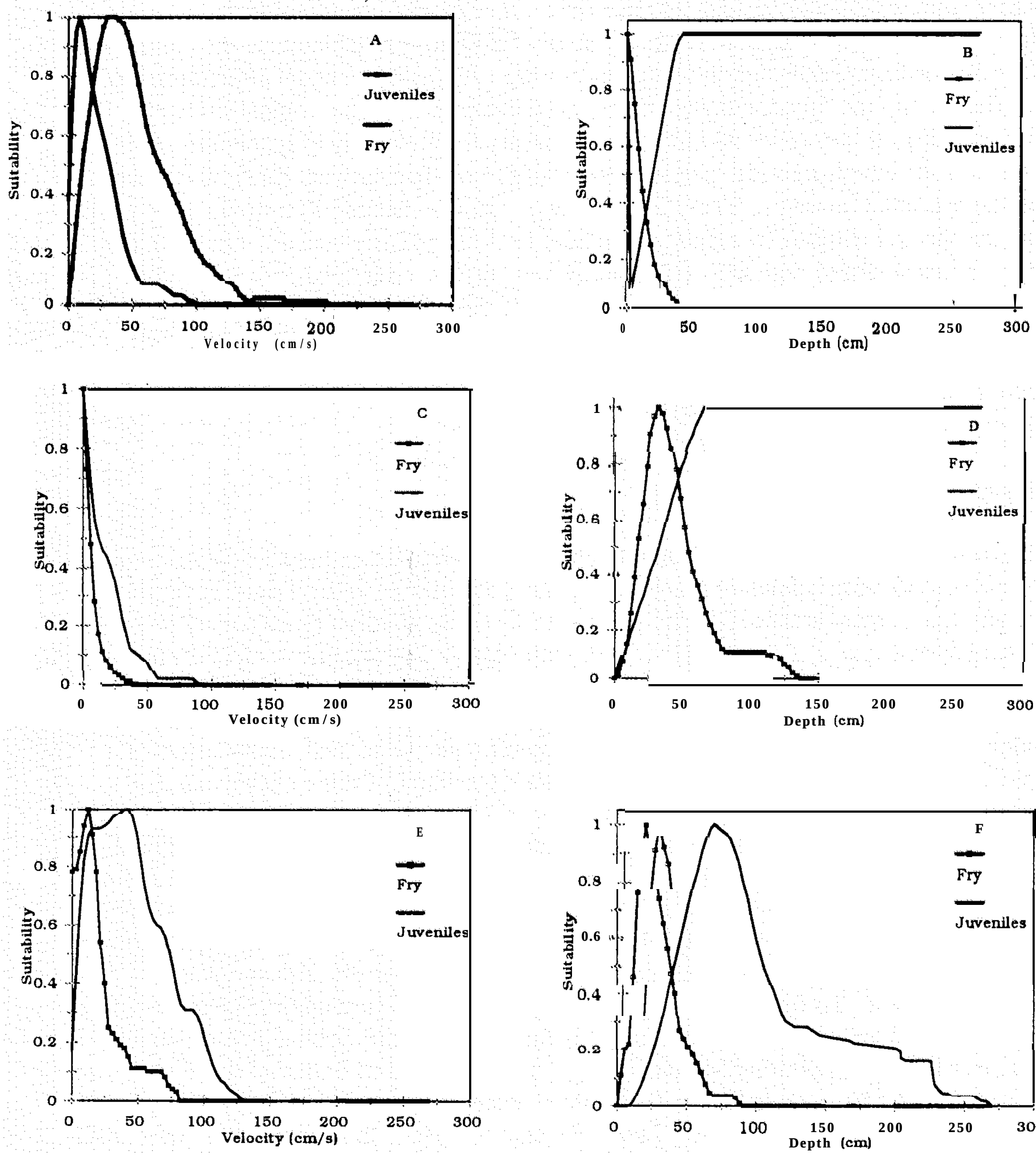

Fig. 1. Velocity and depth HSC for fry (< 50 mm) and juvenile (> 50 mm) Trinity River salmonids (from Hampton 1988). A). Chinook salmon velocity. B). Chinook salmon depth. C). Coho salmon velocity. D). Coho salmon depth. E). Steel head velocity. F). Steelhead depth.

To examine rearing length, growth, and population size at rehabilitation and control sites during 1998, a more intensive electro-fishing and mark-recapture program was conducted. Two replicate 3 by 42 m lanes along both banks of the river at all four rehabilitation and control sites were electro-fished four times during winter and spring 1998 using an equal effort sampling approach (based on time fished, number of crew, and equipment). The original study plan called for sampling all sites bi-weekly from mid-February through early May; high river flows limited this to four sample periods. Starting points of electro-fishing were randomly selected based on the hydraulic transects. Three persons, two with fine mesh (700 u-m) dip nets and one operating the shocker (Smith-Root pulse DC model 12 A) fished one lane at a time. All fish captured were anesthetized with MS-222, identified to species, counted, measured to fork length, allowed to recover, and returned to the river. In addition, chinook salmon were weighed to the nearest 0.1 g and marked with a date and site specific brand (see below). Fish were monitored during the entire procedure for signs of stress. If stress was observed cold river water was added to or shade placed over holding buckets. Rearing or holding indices were calculated as catch per unit effort for all species.

Freeze Branding Mark-Recapture

The methods outlined by Everest and Edmundson (1967) were used to mark, by freeze branding, young of the year chinook salmon at rehabilitation and control sites in the Trinity River during 1998. Ninety five percent ethanol (boiling point -115 C) rather than acetone (boiling point -121 C) was used because it was less noxious to work with. Maslin (personal communication 1997) and Moore (personal communication 1998) suggested that lead type keys such as T, X, 0, I, Z, A, and + work well. Demko and Cramer (1995) also successfully used these letters to brand young salmon. Combinations of these letters were used for site, date, and rehabilitation or control site specific marking of young of the year chinook salmon. Prior to beginning field work, in January 1998, a preliminary marking and survival study using fish from the Trinity River Hatchery in Lewiston, CA was conducted. Hatchery fish were also used to train field personnel in the use of branding techniques. Ninety-one fish were marked with one or more brands during four visits between 15 January and 4 February. Total mortality was 20%. Four of the 18 fish were killed by rough handling, the other 14 vanished and were either eaten by other fish or escaped the trough. The training improved brand recognition and fish survival throughout the process. To further examine mortality from the capture and marking procedure, we captured, marked and placed 30 fish into a 1 m^2 fine mesh (5 mm) holding pen which was held in the river for 2 weeks during March 1998. The pen was placed in partial shade within an area of zero to low (< 50 cm/s) velocity. Cover items were added to the pen. All 30 fish were alive and all brands recognizable after one week. After two weeks 28 fish were present with all marks identifiable and two of the original 30 fish had escaped due to pen failure from rising flows. The pen was removed after 2.5 weeks due to high flow.

Data Analysis and Experimental Design

There are two separate yet non-exclusive approaches to examining differences between rehabilitation sites and the unaltered channel controls concerning fish use via density indices, mark recapture population estimates, habitat indices, and habitat diversity. The first more experimentally and statistically valid approach is to test differences between experimental treatments and control conditions. Ideally one would examine pre- and post-project conditions at the rehabilitation sites (Green 1979, Kondolf 1995). Factors beyond our control rendered this first method impossible. This should be an implicit part of all future rehabilitation projects. This limitation noted, contemporaneous controls were used. Thus the experimental unit is the treatment (each rehabilitation site) and the control unit is each control site in proximity to its corresponding rehabilitation site. Due to time, budget, and personnel limitations it was not possible to set up controls and examine all 9 sites, therefore four sites were randomly selected for study. These four sites and the corresponding reference sites are the samples. The small sample size is recognized.

The first approach to examine fish use is to treat each measure from each treatment and each control as a replicate (n = 4) and use the tests mentioned below to determine if they differ. The idealized linear model is the difference between two treatments in Equation 3.

Equation (3)

[Difference Between Two Treatments] = $T_1 - T_2$. (Modified from Krebs 1989)

T,: [Effect of rehabilitation on fish density} = [Average density on rehabilitation sites] - [Grand mean density for all units].

T,: [Effect of control] = [Average density on control sites] - [Grand mean density for all units].

Habitat and WUA can be substituted for density in the preceding model. This approach was used to test for differences in habitat diversity, physical-flow habitat data, and species diversity between rehabilitation and control sites. This approach avoids pseudoreplication (Hurlbert 1984, Krebs 1989).

The second approach for examining differences in fish use via density indices/ mark-recapture population estimates and for testing physical-flow habitat indices between rehabilitation and control sites is to use data from the 42 x 3 m replicate electro-fishing (or transect hydraulic data). In this case, without pooling treatment and control sites together and doing an overall test, the replicates were the 42 x 3 m lanes n = 2 (n= 3 to 8 for hydraulic data) and differences were examined for individual rehabilitation and control site pairs. This approach, although there is pseudo-replication, was used to increase sample size and address the idea that each site is unique and purported to have a site specific design, Time and budget considerations limit the sample size here as well. This limitation is recognized.

Standard kurtosis and standard skewness were calculated in Statgraphics (Manugistics 1997). In general, most data had standard kurtosis or standard skewness values greater than 2.0, therefore non-parametric tests were used. Weighted usable area and fish use estimates from 1997 sampling were compared using the Mann-Whitney U-test (Zar 1984). The 1998 fish use data were calculated as catch per unit effort (number of fish/total time fished) and compared using the Mann-Whitney-Willcoxan test (Manugistics 1997). For small samples, t-tests were used to compare fish use between rehabilitation and controls at individual sites, The Kolmogorov-Smirnov two sided K-S large sample statistic (Manugistics 1997) was used to test for differences in condition factor, fork length, and weight frequencies between rehabilitation and control sites. Students-t tests and the ANOVA *f*-statistic were used to compare depth, velocity, and river widths.

Species diversity for rehabilitation and control sites was calculated using the Brillouin index because electro-fishing is a selective collection technique (Brower and Zar 1984). Species diversity between rehabilitation and control sites was compared with t-tests (Brower and Zar 1984). Fish use of different micro-habitats (habitat mapping verification) was compared using non-parametric tests (Zar 1984). Habitat diversity indices (Shannon's index, H') were calculated for rehabilitation and control sites and compared using t-tests (Brower and Zar 1984, Zar 1984). Habitat diversity indices were also calculated for the existing channel *(existing channel in this report is defined as the combining rehabilitation and control site data)* and compared to control site diversity indices. This procedure was conducted to examine the idea that habitat diversity is increased in the channel as a result of rehabilitation in combination with areas of riparian encroachment as compared to a channel that is solely composed of riparian encroached banks. The fish species and life stage presence or absence table (Appendix B) was used to assign use to each habitat type at each site for each flow. This data was treated as above to calculate and compare species and life stage habitat diversity for rehabilitation, control sites, and for the existing channel.

To estimate abundance at rehabilitation and control sites from the branding mark recapture data from 1998, the Jolly-Seber method as outlined by Krebs (1989) was attempted. The Peterson method (Brower et al. 1990) was used to calculate population estimates for one site, when the Jolly-Seber method could not be used due to low recaptures. Data collected concurrently for this study was used to compare growth rate and condition factors between the sites as well as use by native and nonnative species. Abundance data from the mark recapture was examined using Equation 3.

Growth rates and condition factors were calculated using methods described by Busacker et al. (1990) and Bagenal and Tesch (1978). I used median fork lengths (Busacker et al. 1990) to calculate specific growth rates for chinook salmon captured during four sample visits in 1998. Chinook salmon c 60 mm were assumed to be all of the same cohort. Specific growth rates were calculated as instantaneous growth rates because fish were collected in intervals of less than one year (Busacker et al. 1990). Growth rates for recaptured fish were calculated similarly, except I used the median fork length of fish from the lane and date for which fish were first marked and their individual fork length at the time of recapture. Growth rates and condition factors were compared with the Mann-Whitney-Willcoxan U-test (Manugistics 1997).

RESULTS

Hydraulic Attributes

The three flows measured during 1997 (Table 2) are within the range of flows (identified by the USFWS 1994) for which rehabilitation was to alleviate flow limited rearing habitat. Figure 2 shows the differences between rehabilitation and control site bed profiles and water surfaces at three flows during 1997. The bed profile elevation difference between the rehabilitation and control sites in Fig. 2 is an artifact of graphic presentation. Rehabilitation removed the riparian berm and widened the river. After six years, during which time there were periods of high flow, the restored bank at the rehabilitation sites remained. The non-restored channel has not significantly widened as a result of these flows.

Rehabilitation sites were significantly wider than control sites at the two higher flows in 1997 (Fig. 2, Table 2). Rehabilitation sites were significantly shallower at all three flows in 1997 (Fig. 2, Table 2). The average mean column velocity across the channel is significantly higher at the rehabilitation sites for the high and low flows during 1997 (Fig. 3, Table 2). There is not a significant difference in mean column velocity between the two treatments at the mid-level flow. The low velocity at station 30 in Fig. 3*a-b* is a result of this station being behind a large boulder. The rehabilitation sites tend to have higher mean column velocities distributed across the channel at all flows as well as having higher maximum velocities in mid-channel (Fig. 3*a-c*).

Physical Fish Habitat

The results of the WA comparisons between the rehabilitation and control sites at three flows during 1997 are shown in Tables 3, 4 and Fig 4. At all three f-lows there is more fry WA on the rehabilitation sites. Fry WA is significantly higher on the rehabilitation sites for steelhead at 13.9 and 60.9 m^3/s, and for chinook salmon at 32.3 and 60.9 m^3/s (Fig. 4*a-c*, Table 3). Coho fry WA is not significantly different at any flow between the rehabilitation and control sites. At the low flow there is more juvenile WA at the control sites and the difference is significant only for steelhead (Fig. 4*a*, Table 3). At the medium and high flows there is more juvenile WA on the rehabilitation sites (Fig, 4*b-c*). The difference is only significant at the high flow for steelhead (Table 3).

Table 2. Results of t-test comparisons of the average depth, mean column velocity, and wetted width at rehabilitation and control sites for three f-lows in the Trinity River during 1997. Data are means. Numbers below are means. Numbers in parentheses are standard errors. N = 16, 13.

	Flow	Rehabilitation	Control	*t*	*P*
Width (m)	60.9 m^3/s	44.96	34.99	4.73	< 0.001
		(1.82)	(0.06)		
	32.3 m^3/s	37.52	31.94	2.29	0.03
		(2.01)	**(0..04)**		
	13.9 m^3/s	33.98	30.97	1.07	0.29
		(2.41)	(1.40)		
Depth (m)	60.9 m^3/s	0.91	1.14	-3.49	0.002
		(0.05)	(0.04)		
	32.3 m^3/s	0.76	1.01	-2.67	0.01
		(0.04)	(0.05)		
	13.9 m^3/s	0.57	0.71	-2.11	0.04
		(0.05)	(0.04)		
Velocity (m/s)	60.9 m^3/s	1.07	0.90	**-4.73**	**< 0.001**
		(0.06)	(0.06)		
	32.3 m^3/s	0.78	0.77	**-0.37**	**0.71**
		(0.04)	(0.06)		
	13.9 m^3/s	0.58	0.43	**-5.51**	**< 0.001**
		(0.01)	(0.02)		

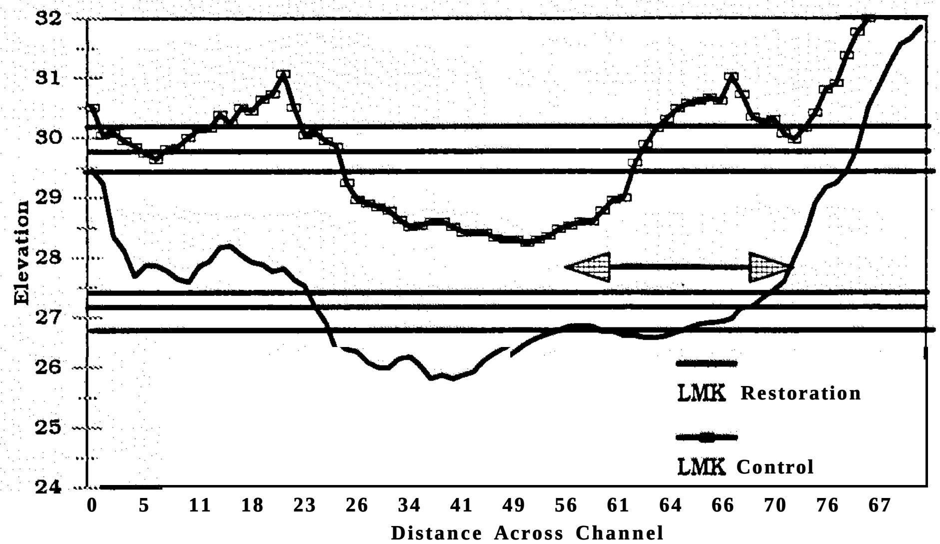

Fig. 2. Bed profiles and water surfaces for one (LMK xsec. # 2) rehabilitation and one control site cross section in the Trinity River, CA during 1997. Horizontal lines indicate water surfaces at 13.9, 32.3, and 60.9 m^3/s. Arrow indicates the constructed bank.

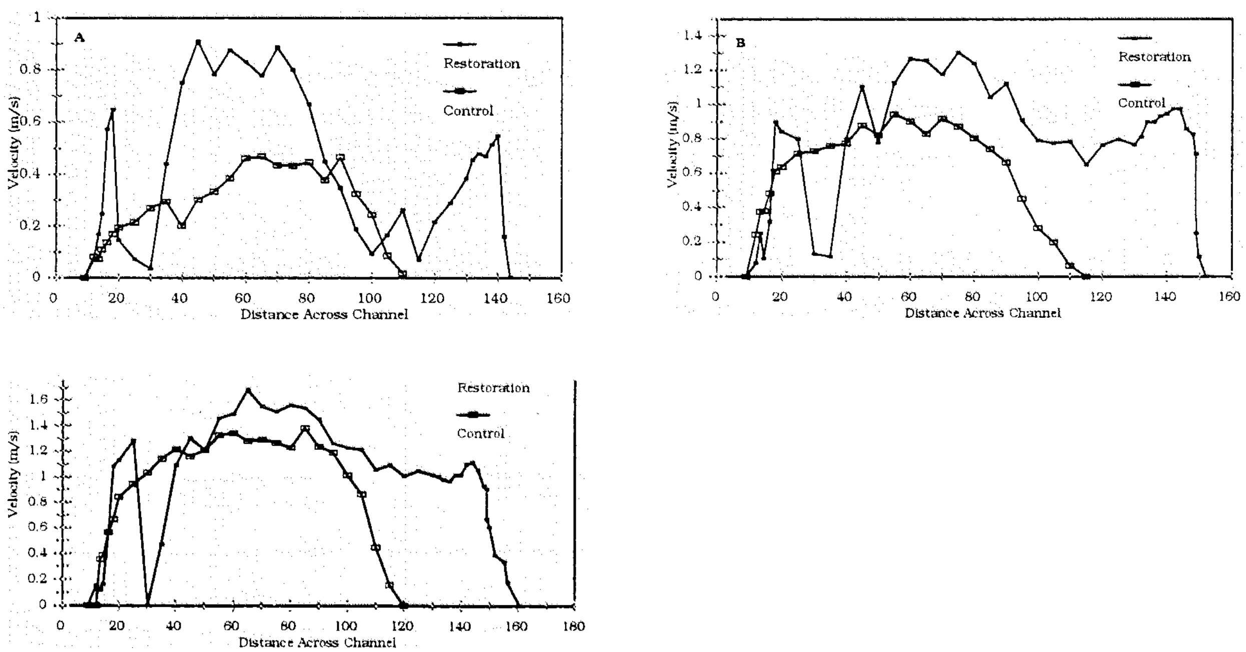

Fig. 3. Mean column velocity distributions across the channel for a rehabilitation and a control site transect (LMK xsec. # 2) in the Trinity River at three f-lows during 1997. A. 13.9 m^3/s. B. 32.3 m^3/s. C. 60.9 m^3/s.

Table 3. The U and p-values for Mann-Whitney comparisons of salmonid habitat indices (weighted usable area) between rehabilitation and control sites on the Trinity River at three Lewiston Dam releases during 1997. Data are from 16 rehabilitation site and 13 control site channel cross sections.

Species	Life Stage	Flow					
		13.9 m^3/s		32.3 m^3/s		60.9 m^3/s	
		U	P	U	P	U	P
Steelhead	Juvenile	145	0.07	117	0.25	146	0.06
	Fry	179	0.001	152	0.01	125	0.19
Coho Salmon	Juvenile	122	0.20	100	0.35	125	0.22
	Fry	120	0.30	125	0.22	125	0.22
Chinook Salmon	Juvenile	135	0.15	102	0.29	129	0.19
	Fry	105	0.28	146	0.02	192	0.01

When the WUA data are examined using an idealized linear model (Equation 3) the effect of rehabilitation on fish habitat is an overall increase for chinook salmon fry at 32.3 and 60.9 m^3/s (Table 4). At the low flow the effect of rehabilitation appears to be a decrease in habitat for chinook salmon and steelhead juveniles. Fry WUA is increased at the low flow.

Table 4. The overall difference (Equation 3) between salmon habitat indices (weighted usable area m^2/m) from rehabilitation and control sites on the Trinity River during 1997 for three flows. N = 16, 13. Negative numbers indicate decrease in WUA due to rehabilitation. Asterisks indicate significant differences at $p = 0.05$.

Flow	Steelhead		Coho		Chinook	
	Juveniles	Fry	Juveniles	Fry	Juveniles	Fry
13.9 m^3/s	-1.45	0.42*	0.67	0.09	-0.71	0.73
32.3 m^3/s	-0.03	0.22*	0.68	0.11	0.22	0.63*
60.9 m^3/s	0.93	0.37	0.89	0.29	0.48	0.71*

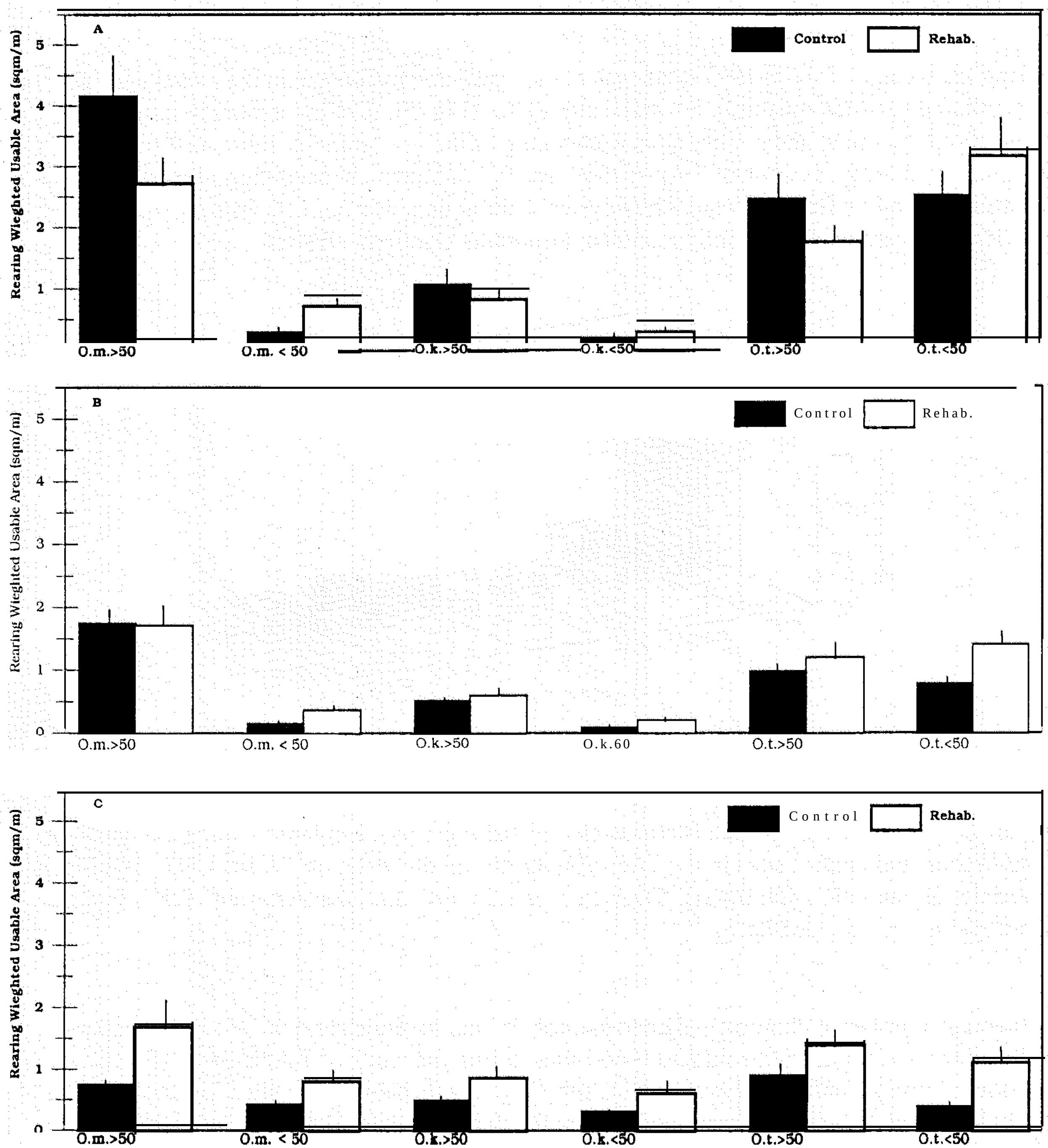

Fig. 4. Mean salmon fry and juvenile rearing weighted usable area for rehabilitation and control sites on the Trinity River at three flows during 1997. A). 13.9 m^3/s. B). 32.3 m^3/s. C). 60.9 m^3/s. *O. m.* is *Oncorhynchus mykiss* (steelhead). *O. k.* is *O. kisutch* (coho). *O. t.* is 0. *tshawytscha* (chinook). Thin lines represent 1 SE, n = 16, 13.

Fish Use 1997

During the week of 7 April 1997 there was not a significant difference in the average number of fish captured between rehabilitation and control sites (Fig. 5). The most numerous species at this time at both treatment and control sites were young of the year chinook salmon. The Lewiston Dam release during the week of 7 April 1997 was 9.7 m^3/s which, accounting for tributary input, is similar to the low flow for which the physical habitat data was collected during this year. Sticklebacks were not consistently recorded during this sampling effort.

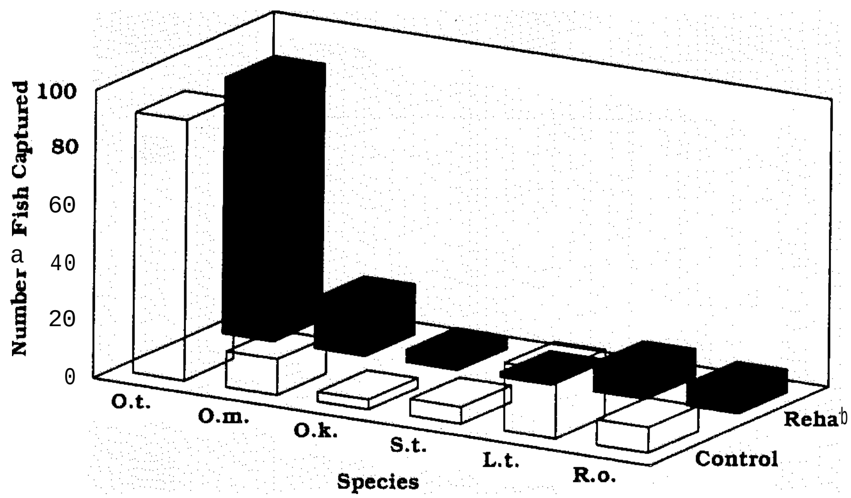

Fig. 5. The mean number of fish captured electro-fishing 3 by 42 m lanes along both banks of rehabilitation and control sites in the Trinity River during the week of 7 April 1997. See Fig. 4 for species abbreviation definitions. Data are means, n =4. *S.t.* is brown trout. *L.t.* is Pacific Lamprey. *R.o.* is speckled dace.

The average number of chinook and coho salmon fry and juveniles and the average number of steelhead fry was higher at the rehabilitation sites during the week of 7 April 1997 (Fig. 6). Chinook salmon juvenile catch was significantly higher at rehabilitation sites (Fig. 6, Table 5). Steelhead fry catch was significantly higher on rehabilitation sites during the week of 7 April 1997 (Fig. 6, Table 5). The pattern of fish CPU (Fig. 6), except for juvenile chinook and coho salmon, was similar to the WUA patterns for the 9.7 m^3/s Lewiston Dam release (Fig. 4a). Steelhead fry WUA and steelhead fry use were significantly higher at the rehabilitation sites (Tables 4, 5). Steelhead juvenile WUA was significantly higher at the control sites (Fig. 4*a*, Table 4) and steelhead juvenile use not different between treatments (Fig. 6). Because only one lane was sampled along each bank at each rehabilitation and control site statistical comparisons of fish use by site for 1997 were not possible.

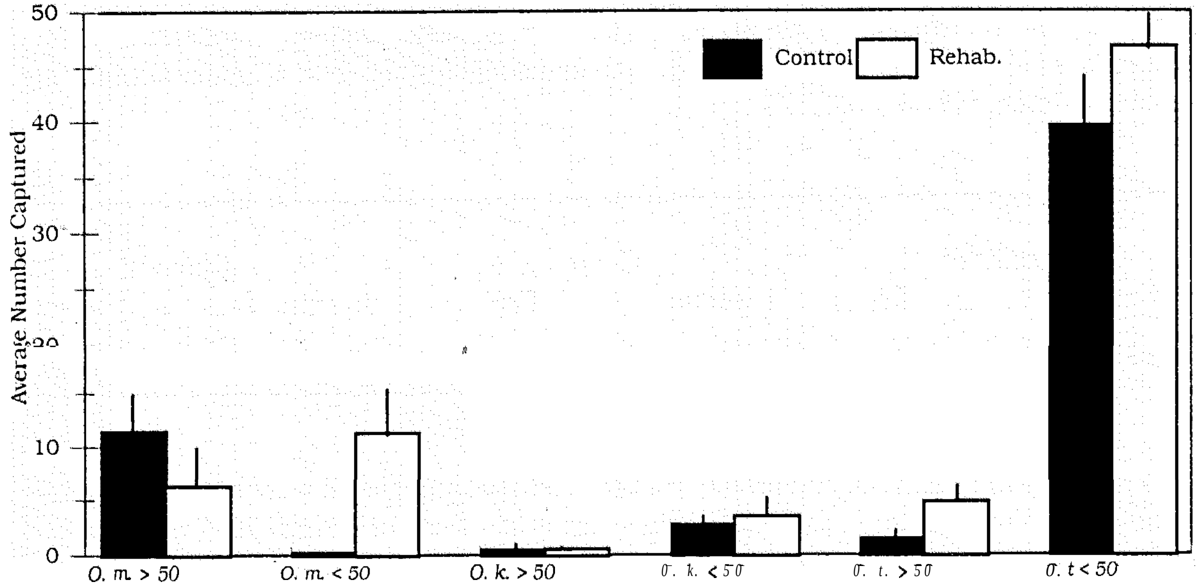

Fig. 6. Mean number of fry and juvenile salmon captured at rehabilitation and control sites in the Trinity River during the week of 7 April 1997. Data are means, n = 4. Thin lines represent 1 SE. See Fig. 4 for species abbreviations.

Table 5. The *U* andp-values from Mann-Whitney comparisons of salmonid fry and juvenile abundance between rehabilitation and control sites on the Trinity River during the week of 7 April 1997. Data are from electro-fishing 3 by 42 m lanes along both banks at rehabilitation and control sites. N = 4.

Species	Juvenile		Fry	
	U	P	*U*	P
S teelhead	10	0.33	16	0.01
Coho Salmon	8	0.42	8.5	0.49
Chinook Salmon	14	0.05	12	0.15

When the fish capture data are examined using Equation 3 the effect of rehabilitation at 13.9 m^3/s on fish use is an overall increase for steelhead, coho salmon, and chinook salmon fry (Table 6). Chinook salmon juvenile show an increase as a result of rehabilitation while there was no difference for coho and steelhead (Table 6). Statistical significance is shown in Table 5.

Table 6. The overall difference (Equation 3) in total catch of fry and juvenile salmon between rehabilitation and controls on the Trinity River, CA during 1997, Data are from electro-fishing 42 by 3 m lanes along both banks of rehabilitation and control sites. N = 4. Asterisks indicate significant differences at $p = 0.05$.

Steelhead		Coho		Chinook	
Juvenile	Fry	Juvenile	Fry	Juvenile	Fry
-5.02	11.0”	0.0	0.75	3.25”	7.25

Chinook salmon, coho salmon, and brown trout fork length frequencies were not significantly different between rehabilitation and control sites during the week of 7 April 1997 (Fig. 7*a*, c, *d*; Table 7). Steelhead fork length frequencies were significantly different between rehabilitation and control sites (Fig 7*b*, Table 7). Steelhead fry were more abundant at rehabilitation sites and juveniles were more associated with control sites during the week of 7 April 1997. The significant difference in use of restored sites by fry and control sites by juvenile steelhead corresponds with WUA for this flow (Figs. 4 a, 7*b*; Tables 3 and 7). Brown trout were more abundant at control sites (Figs. 5, 7*d*).

The number of fish captured on the constructed bank was not significantly greater than the number of fish captured on the unmodified banks at rehabilitation sites in the Trinity River during the week of 7 April 1997 (Fig. 8, Table 8). More chinook salmon, steelhead, coho salmon, and speckled dace were generally captured on the constructed bank while more lamprey and brown trout were found on the unmodified bank. When examined by site, more chinook salmon were captured on the constructed bank compared to the unmodified bank at four rehabilitation sites (Fig 9*a*). Three sites had more steelhead on the constructed bank (Fig 9b). Coho salmon were only observed at two of the four rehabilitation sites and more were associated with the constructed bank at one site (Fig 9*c*).

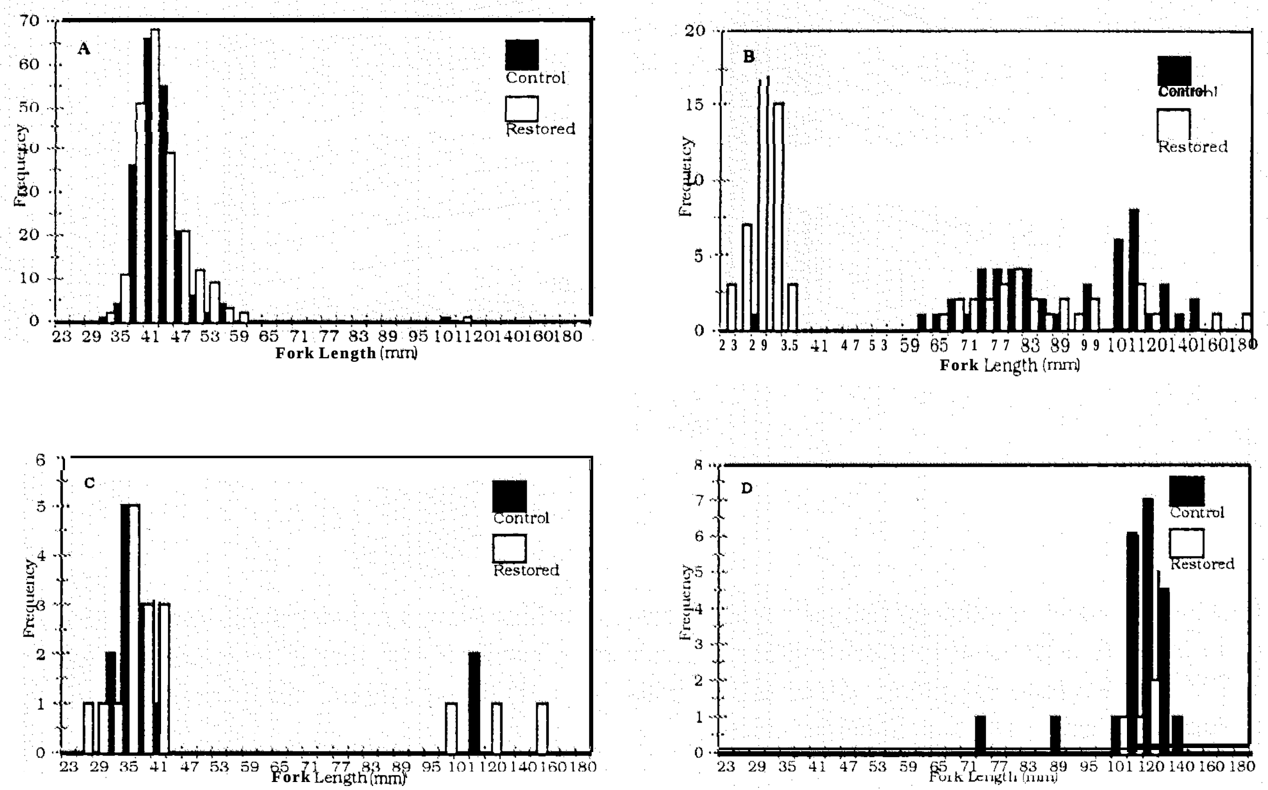

Fig. 7. Salmonid fork length frequencies from rehabilitation and control sites on the Trinity River during the week of 7 April 1997. A). Chinook salmon. B). Steelhead. C). Coho salmon. D). Brown trout.

Table 7. Results of Mann-Whitney comparisons of salmonid fork length distributions between rehabilitation and control sites on the Trinity River during the week of 7 April 1997. The *t*-values are from the normal approximation. Numbers in parenthesis are sample sizes.

Chinook Salmon	Steelhead	Coho Salmon	Brown Trout
t =-1.20 (219,196) $p = 0.25$	t=-3.35 (73, 49) $p = 0.005$	(U = 115) $p = 0.2$	(U = 61) p = 0.3

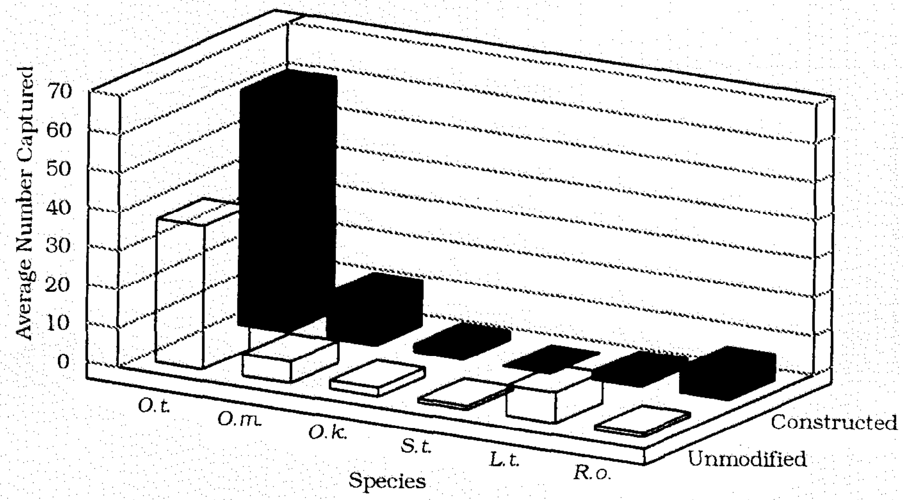

Fig. 8. The mean number of fish captured by electro-fishing 42 x 3 m lanes along the constructed and unmodified banks at four rehabilitation sites on the Trinity River during the week of 7 April 1997. *O. t.* is chinook salmon. *O. m.* is steelhead. *O. k.* Is Coho salmon. *S.t.* is brown trout. *L.t.* is Pacific lamprey. *R. o.* is Speckled dace.

Table. 8. Man-Whitney comparisons of the number of fish captured by electro-fishing 42 x 3 m lanes along the constructed and unmodified banks at four rehabilitation sites on the Trinity River during the week of 7 April 1997.

Species	U-Statistic	p-Value
Chinook Salmon	$3 < U < 13$	0.09
S teelhead	$3.5 < u < 12.5$	0.12
Coho Salmon	$7 < U < 9$	0.43
Brown Trout	$2 < U < 14$	0.10
Lamprey	$4.5 < U < 11.5$	0.15
Dace	$5 < U < 11$	0.22

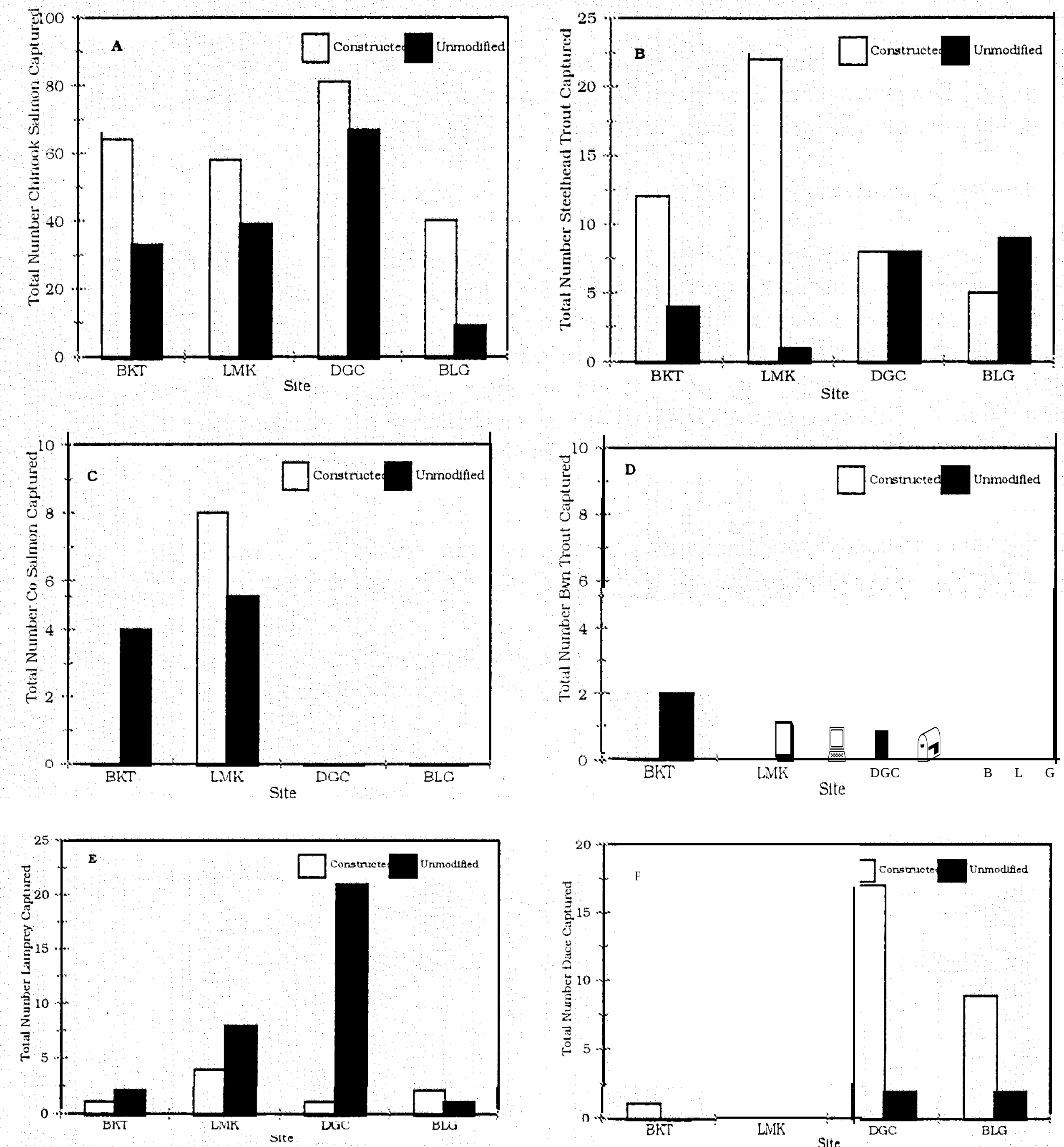

Fig. 9. Total number of fish captured by electro-fishing the constructed and unmodified banks at four rehabilitation sites on the Trinity River during the week of 7 April 1997.

All coho Salmon captured during 1997 were of hatchery origin as evidenced by fin clips. Brown trout were only captured on the unmodified banks at rehabilitation sites during 1997 (Fig. 96). More lamprey were captured on the unmodified banks at three of the four rehabilitation sites (Fig. 9e). Dace were more associated with the constructed banks at three of the rehabilitation sites and were not captured on either bank at the other (Fig. 9*f*).

Preliminary Mark-Recapture 1997

On 29 April 1997, 36 young of the year chinook salmon were marked at the Douglas City rehabilitation site. Four days later we recovered six marked fish, a recapture rate of 17%. The spring release of 56 m^3/s ramp up began on 5 May 1997. As a preliminary test to examine lateral migration along the constructed bank, 16 young of the year chinook salmon were marked and released at the Douglas City rehabilitation site. By 8 May 1997 the river flow was up to at least 56 m^3/s. The same area at the Douglas City rehabilitation site was sampled and marked fish were not captured. In late-April chinook salmon reared at a rehabilitation site for at least 3 days.

During four consecutive sampling visits (the mark recapture effort) to the Douglas City rehabilitation site between 9 April and 8 May 1997, more chinook salmon were captured on the constructed bank (Fig. 10*a*). When each date is treated as a sample (n = 4) there is a significant difference in total fish captured between banks ($Z = -3.04$, $p < 0.001$). Similarly, more steelhead were captured on the constructed bank of the Douglas City rehabilitation site during consecutive sampling visits in 1997 (Fig. 10*b*). Treating each date as a separate sample (n = 4) the difference is significant ($Z = -3.2$, $p < 0.001$).

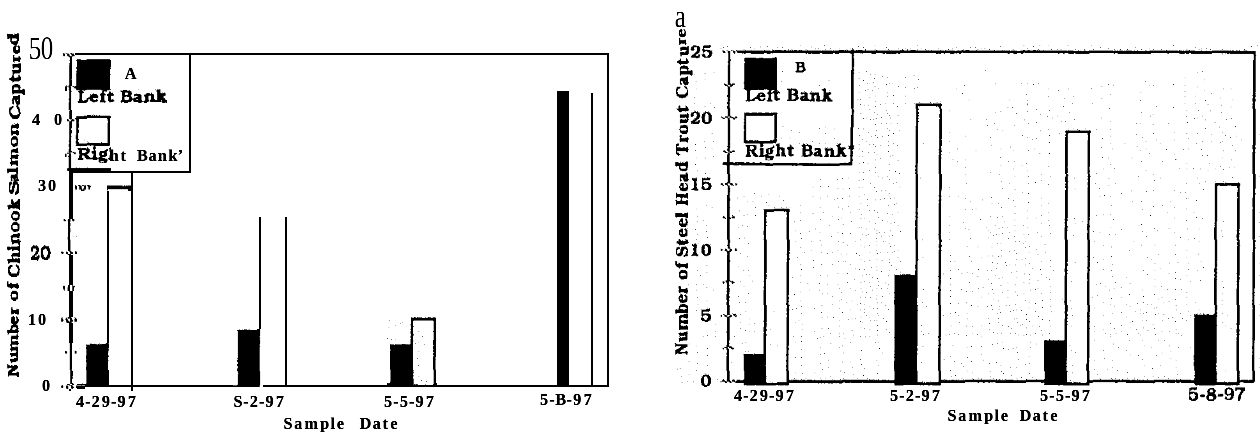

Fig. 10. Total number of fish captured by electro-fishing 3 by 42 m lanes along both banks of the Douglas City rehabilitation site on the Trinity River during spring 1997. A. Chinook salmon. B. Steelhead. Asterisks indicate the constructed bank.

Chinook salmon were larger on the constructed bank of the Douglas City rehabilitation site during three consecutive sampling visits in spring 1997 (Fig. 11 a, c, e). When the data are lumped for all three dates the difference is significant (K-S = 1 .5, $p < 0.02$). This dif not significant when fish collected in an off channel area on the unmodified bank

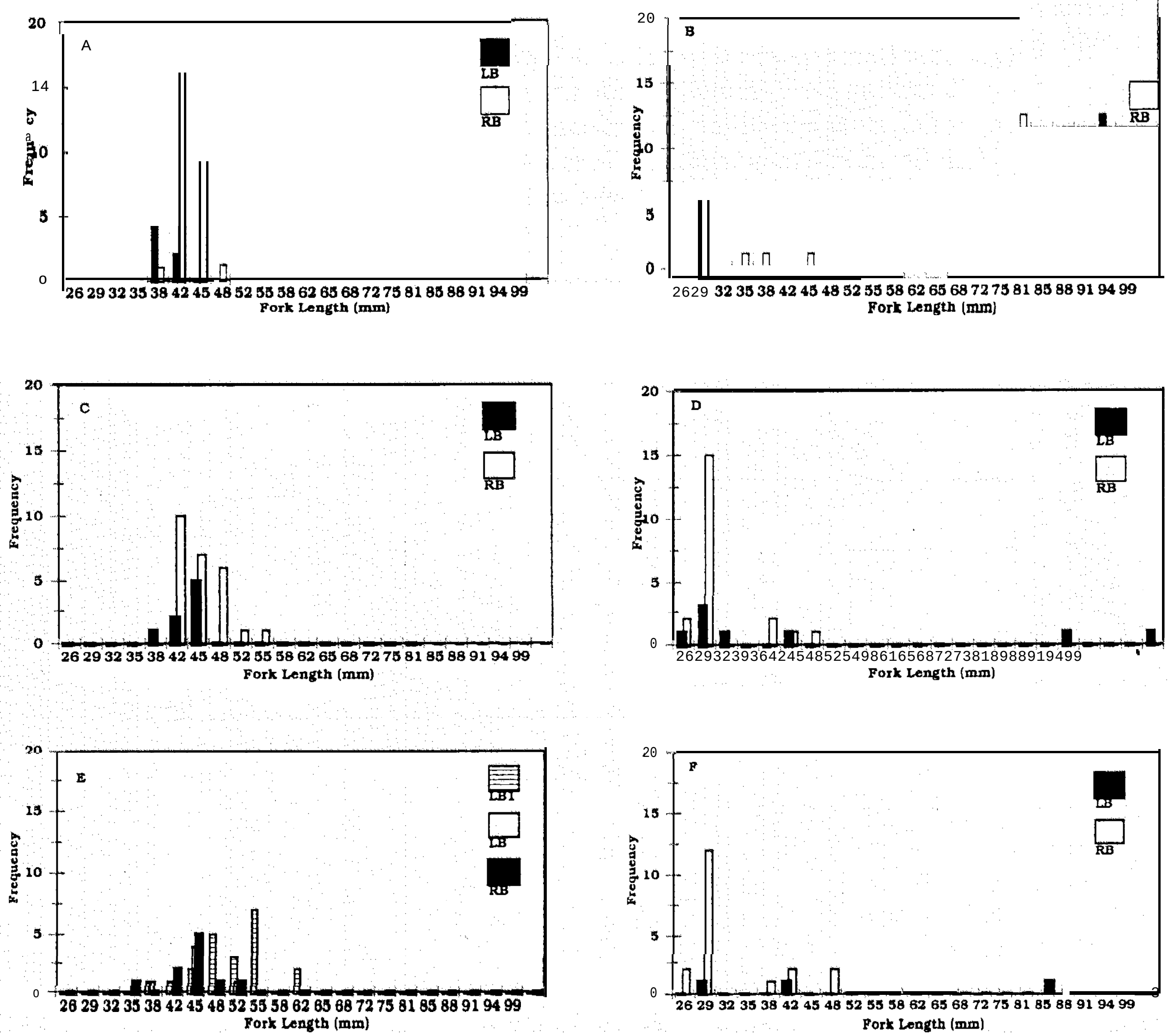

Fig. 11. Chinook salmon and steelhead fork length frequencies on constructed and unmodified banks at the Douglas City during 1997. A). Chinook salmon on 29 April. B). Steelhead on 29 April. C). Chinook salmon on 2 May. D). Steelhead on 2 May. E). Chinook salmon on 5 May. F). Steelhead on 5 May. The RB is the constructed bank. The left bank (LB) is the unmodified bank. LB1 is an off channel area.

on 5 May 1997 are included. This area existed on this date as the flows were up to 53 m^3/s and the riparian berm was inundated. Steelhead were larger on the constructed bank of the Douglas City rehabilitation site during three sampling visits in spring 1997 (Fig. 11 *b*, *d*, *f*). When the data are lumped for all three dates the difference is not significant (K-S = 1.2, p = 0.11).

Fish Use 1998

During 1998, Lewiston Dam releases were scheduled to be 9.9 m^3/s all winter with an increase to approximately 40 m^3/s in early spring (P. Zedonis, Per. Comm.). The study plan called for intensive electro-fishing at the rehabilitation and control sites on a bi-weekly basis beginning in mid-February. High flows, due to numerous storms and flood events, limited sampling to five visits, with only one sampling period having flows within the original range (Fig. 12).

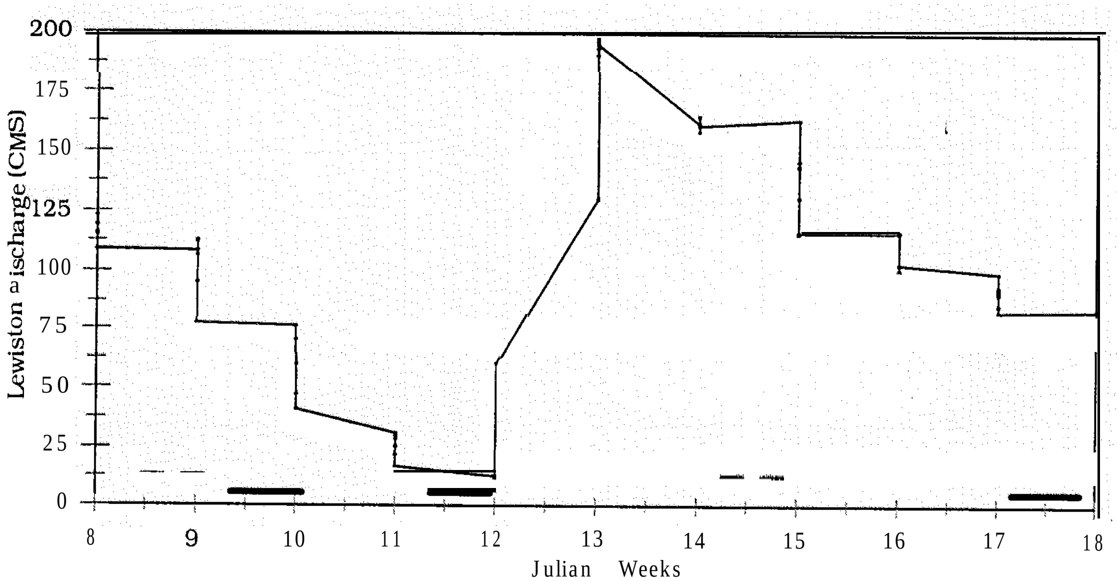

Fig. 12. Trinity River at Lewiston stream flow for winter and spring 1998. Week 8 beginning on 16 February, 1998. Dark horizontal lines indicate weeks all sites were sampled. Dashed lines indicate weeks when not all sites were sampled. (Data from CDEC 1999).

One 42.5 by 3 m lane along both banks of the Douglas City rehabilitation and control sites was sampled in early February 1998 (week eight) and two 42.5 by 3 m lanes were electro-fished along each bank of all four rehabihtation and control sites three times during winter 1998 (weeks 9, 11, and 18). Only one bank at one site was sampled during week 14 because flows were to high to safely cross the river. More chinook salmon, Pacific lamprey, and sticklebacks were captured at the Douglas City rehabilitation site than at the control site on week 8 (Fig. 13*a*). More steelhead were captured at the Douglas City control site during week eight. During week nine there was not a significant difference in the total catch per unit effort for any species between rehabilitation and control sites (Fig. 130, Table 9). The average catch per unit effort of chinook salmon and Pacific lamprey was higher at rehabilitation sites during week nine (Fig, 13*b*). During week 11 the total catch per unit effort of chinook salmon and Pacific lamprey was significantly higher at rehabilitation sites (Fig. 13*c*, Table 9). The catch per unit effort of steelhead, brown trout, stickleback, and speckled dace was non-significantly higher at rehabilitation sites during week 11 (Fig. 13*c*, Table 9). During week 18 the total catch per unit effort of chinook and coho salmon and steelhead was significantly higher at control sites (Fig. 13*d*, Table 9). Only speckled dace showed slightly higher catch per unit effort on rehabilitation sites during week 18 (Fig. 13*d*, Table 9).

More chinook salmon fry were captured at the Douglas City rehabilitation site than at the control site during week 8 (Fig. 14*a*). No juvenile chinook salmon were captured during week 8. There was not a significant difference in the catch per unit effort of fry and juvenile chinook salmon at rehabilitation and control sites during week 9 (Fig. 146, Table 10). However, non-significantly more fry were captured at rehabilitation sites and more juveniles were captured at control sites during week 9 (Fig, 140). Chinook salmon fry and juvenile catch per unit effort was significantly different between rehabilitation and control sites during week 11 (Fig. 14*c*, Table 10). More fry were captured at rehabilitation sites and more juveniles were captured at control sites. During week 18 there was a significant difference in catch per unit effort of chinook salmon juveniles between rehabilitation and control sites (Fig. 14*d*, Table 10). More fry and juvenile chinook salmon were captured at control sites during week 18.

More steelhead juveniles were captured at the Douglas City control site than at the rehabilitation site during week 8 (Fig. 15*a*). No steelhead fry were captured during weeks 8 and 9. There was no difference in catch per unit effort of steelhead between rehabilitation and control sites during week 9 (Fig. 15*b*, Table 10). Catch per unit effort of juvenile steelhead > 100 mm was significantly different between rehabilitation and control sites during week 11 (Fig. 15*c*, Table 10). Control sites had higher catch per unit effort of steelhead juveniles during week 11. More steelhead fry were captured at rehabilitation sites during week 11 (Fig. 15*c*, Table 10). During week 18 the catch per unit effort of steelhead juveniles < 100 mm was significantly higher at control sites (Fig. 15*d*, Table 10). The catch per unit effort for steelhead juveniles > 100 mm was not significantly higher at control sites during week 18 (Fig 15*d*, Table 10). There was no difference in catch per unit effort of steelhead fry between rehabilitation and control sites during week 18 (Fig. 15, Table 10).

Because bank rehabilitation projects on the Trinity river were intended to increase fry and juvenile salmonid habitat between flows of4.2 and 42.4 m^3/s (USFWS 1994) and due to sampling difficulties associated with higher flows, the intensive analysis of fish

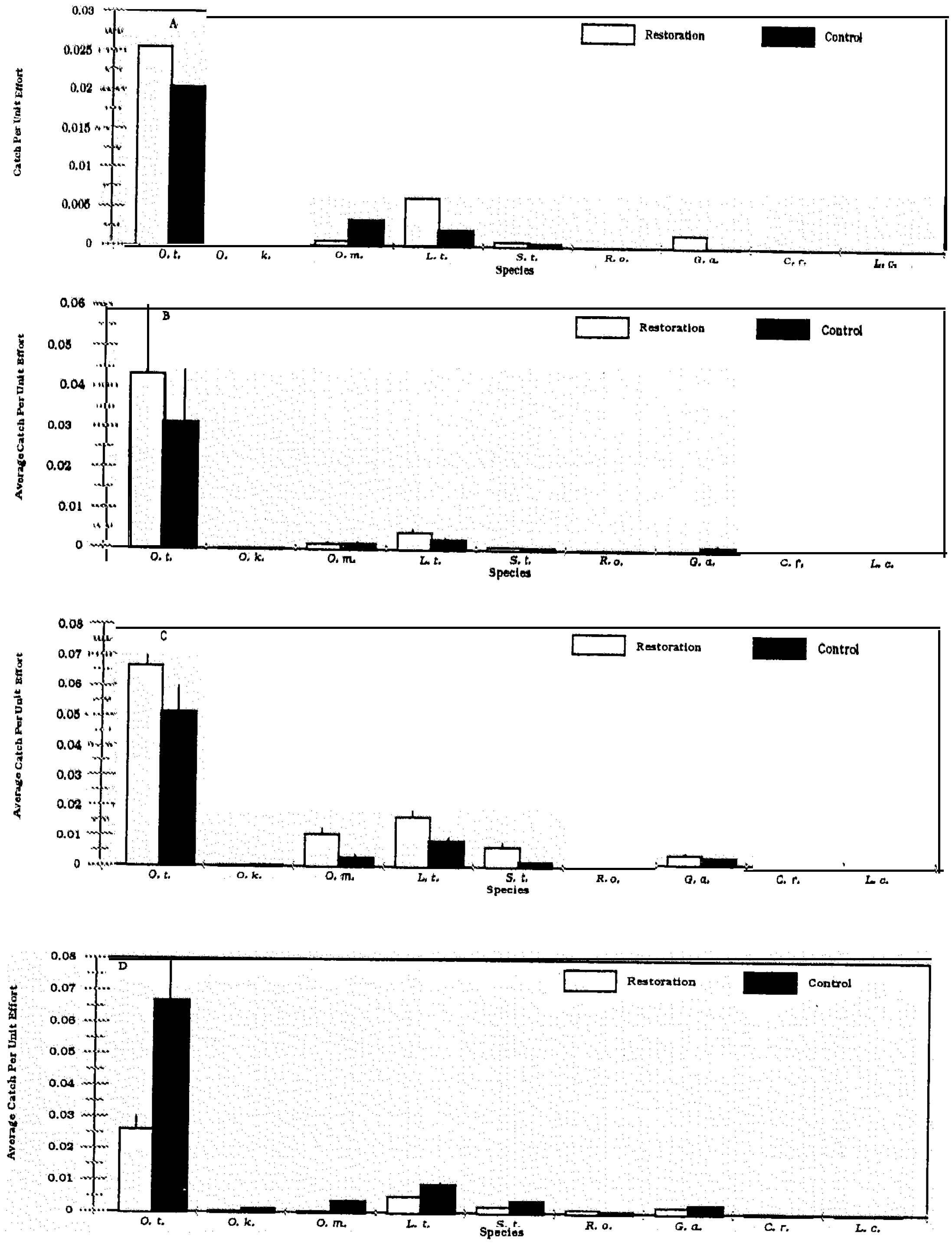

Fig. 13. Mean catch per unit effort for rehabilitation and control sites in the Trinity River during 1998. A). Week 8. B). Week 9. C). Week 11. D). Week 18. Thin lines represent 1 SE. Abbreviations along X-axis are species names (see Methods).

Table 9. Mann-Whitney U and p-values from comparisons of the total catch per unit effort from rehabilitation and control sites in the Trinity River during 1998. Week 9 begins 23 February. Week 11 begins 9 March. Week 18 begins 27 April. N = 4.

Species	Week	U - Value	p - Value
Chinook Salmon	9	(10)	0.33
	11	(12.5)	0.12
	18	(13)	0.09
Coho Salmon	9	(5.5)	0.55
	11	(10)	0.30
	1s	(12)	0.15
Steelhead Trout	9	(10)	0.33
	11	(10)	0.33
	18	(14)	0.05
Brown Trout	9	(9)	0.44
	11	(9)	0.44
	18	(9)	0.44
Pacific Lamprey	9	(9)	0.50
	11	(13)	0.09
	18	(10)	0.33
Speckled Dace	9	(8.5)	0.52
	11	(10)	0.30
	18	(10)	0.33
Stickle Back	9	(11)	0.20
	11	(9)	0.55
	18	(8.5)	0.44
Klamath Sucker	9	(10)	0.30
	11	(10)	0.30
	1s	(10)	0.30
Green Sunfish	9	None collected either site	
	11	(10)	0.30
	18	None collected either site	

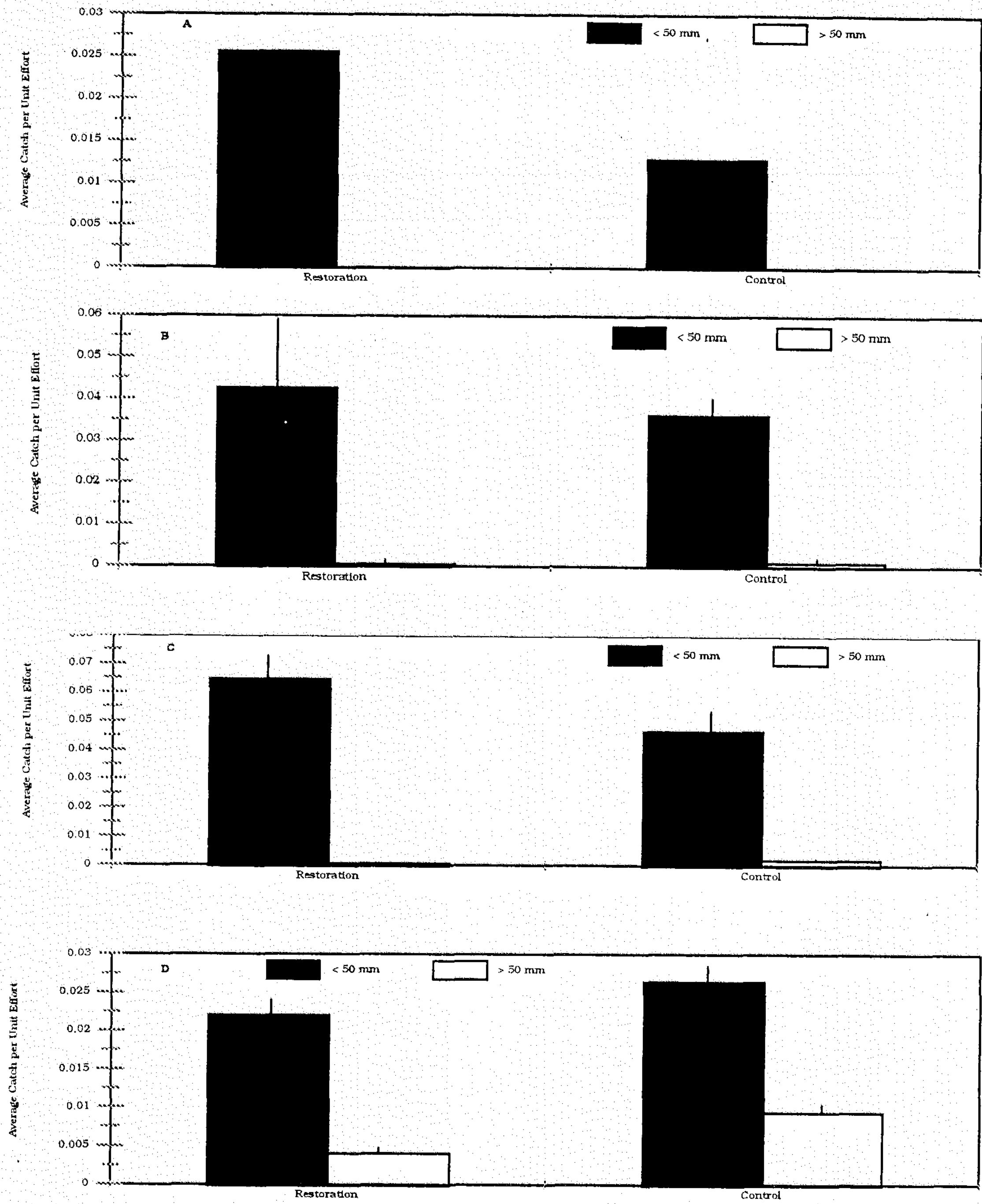

Fig. 14. Mean catch per unit effort of chinook salmon fry (< 50 mm) and juveniles (> 50 mm)from rehabilitation and control sites on the Trinity River during 1998. A). Week 8. B). Week 9. C). Week 11. D). Week 18. Data are means, n = 4. Thin lines represent 1 SE.

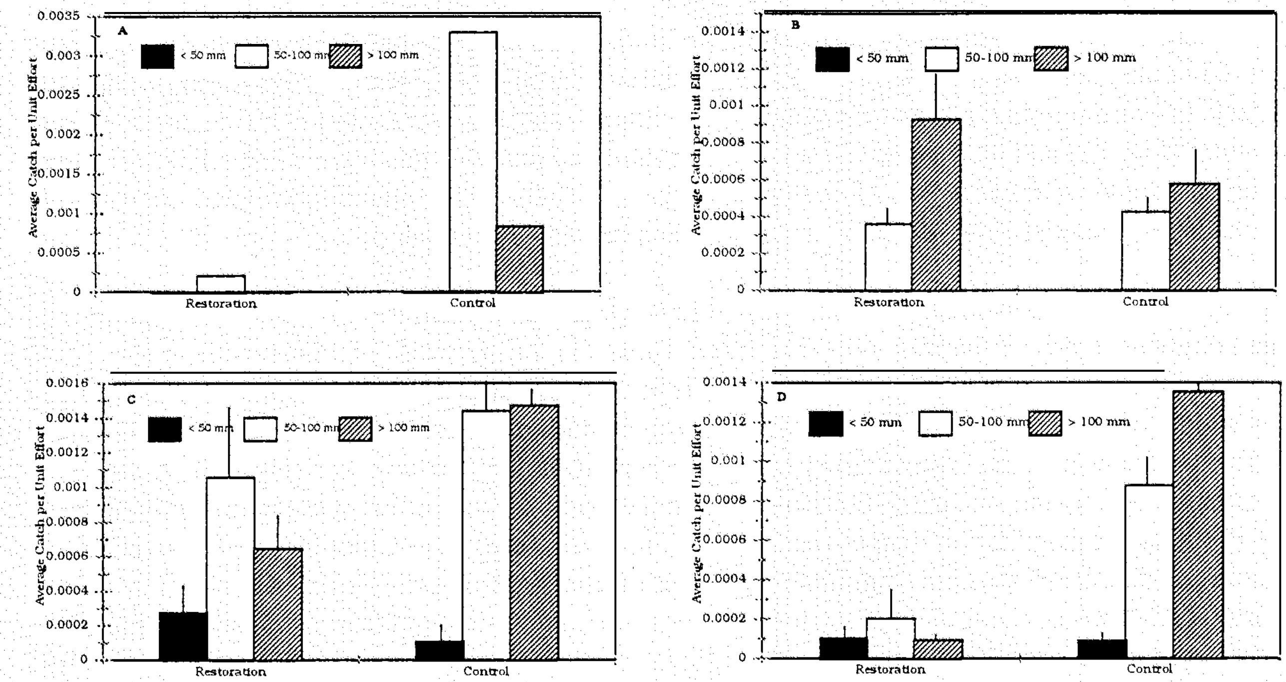

Fig. 15. Mean catch per unit effort of steelhead fry and juveniles from rehabilitation and control sites on the Trinity River during 1998. A). Week 8. B). Week 9. C). Week 11. D). Week 18. Data are means, n = 4. Thin lines represent 1 SE.

Table 10. Mann-Whitney comparisons of chinook salmon and steelhead fry and juvenile catch per unit effort for rehabilitation and control sites on the Trinity River during 1998.

Species	Week	Fry	Juveniles	
		< 50 mm	50 - 100 mm	> 100 mm
Chinook Salmon	9	u = 9, p= 0.43	u = 8.5, p= 0.44	
	11	u = 13, p = 0.09	u = 14, p= 0.05	
	18	U = 10, p = 0.33	u= 13, p = 0.09	
Steelhead	9	U = 8, p = 0.50	U = 9.5, p= 0.35	U = 10, p = 0.67
	11	u = 10, p= 0.31	u = 10, p= 0.33	U = 16, p < 0.03
	18	U = 8.5, p= 0.50	u = 14, p= 0.03	u= 11, p = 0.20

use, density, size, and diversity between rehabilitation and control sites during 1998 was limited to data collected during week 11 (week beginning 9 March 1998). River flows during sample week 11 were within the range for which rehabilitation projects were intended to increase rearing habitat (Fig. 12) and all transects at all rehabilitation and control sites were sampled. River flows during sample weeks 8, 9, and 18 were above those for which the rehabilitation projects were intended to increase rearing habitat as the riparian berm was inundated.

Total chinook salmon catch per unit effort was not significantly different between rehabilitation and controls at any of the four sites (Fig. 16*a*, Table 11) during week 11. Due to the small sample size t-tests were used to compare catch per unit effort between rehabilitation and control by site for week 11 samples. Two of the four rehabilitation sites showed average catch per unit effort of chinook salmon to be higher than their corresponding control sites (Fig. 16). When examined by site and size class, chinook salmon fry catch per unit effort was significantly higher at Bell Gulch rehabilitation than at the control (Fig. 16*b*, Table 11). Chinook salmon juvenile catch per unit effort was only significantly higher on the control at the Bell Gulch site (Fig. 16*c*, Table 11). Two of the four sites showed higher mean catch per unit effort of chinook salmon fry (< 50 mm) at rehabilitation sites (Fig. 16*c*). Two of the four sites showed higher average catch per unit effort of chinook salmon juveniles (> 50 mm) at control sites (Fig. 16*c*).

Table 11. Results of t-test comparisons of total, fry (< 50 mm), and juvenile (> 50 mm) chinook salmon catch per unit effort between rehabilitation and control sites on the Trinity River during week 11 (9 March) 1998. N = 2.

Site	< 50 mm	> 50 mm	Total
Buck Tail	t = 0.12 p = 0.9	t = -1.34 p = 0.2	t = - 0.12 p = 0.91
Lime Kiln	t = 0.67 p = 0.6	t = - 0.84 p = 0.6	t = - 0.66 p = 0.57
Douglas City	t = 1.09 p = 0.5	t = - 0.24 p = 0.8	t = 1.10 p = 0.38
Bell Gulch	t = -3.99 p = 0.06	t =3.51 p = 0.04	t = 1.48 p = 0.27

When catch per unit effort data are examined using Equation 3 the effect of rehabilitation is an overall increase for all fish except coho salmon and green sun fish (Table 12). Chinook salmon and steelhead juveniles show a slight decrease as a result of rehabilitation (Table 12). Chinook salmon and steelhead fry show and increase due to rehabilitation (Table 12).

Chinook salmon fork length distributions during week 11 were significantly different between rehabilitation and control sites on the Trinity River (Fig. 17 A, K-S = 4.9, p = 0.0). Median chinook salmon lengths were significantly smaller at rehabilitation sites (U = 37334, p < 0.001). Chinook salmon weight frequencies were significantly different between rehabilitation and control sites during week 11 (Fig. 17 B, K-S = 8.0, p < 0.0001). Median chinook salmon weights were significantly less at rehabilitation sites during week 11 (U = 38742, p = 0). Thus the condition factor frequencies were significantly different between rehabilitation and control sites during week 11 (Fig. 17 C, K-S = 3.14, p < 0.0001). Median chinook salmon condition factors were significantly lower at rehabilitation sites during week 11 (U = 369574, p < 0.0001).

Steelhead fork length distributions were not significantly different between rehabilitation and control sites during week 11 (K-S = 1.10, p = 0.18). Median steelhead fork lengths were not different between the two treatments (W = 754, p = 0.06). Coho salmon fork length distributions were not significantly different between rehabilitation and controls (K-S = 1.15, p = 0.14). However, median fork lengths were significantly larger at control sites (W = 8, p = 0.05). Pacific lamprey total length distributions were not different between treatments (K-S = 0.49, p = 0.97). Median lamprey total lengths did not differ (W = 9306, p = 0.93). Brown trout fork length distributions were not different between treatments (K-S = 1.16, p = 0.13). Yet brown trout median fork lengths were significantly larger at control sites (W = 508, p = 0.04).

Table 12. The effect of rehabilitation on total, fry, and juvenile catch per unit effort for all species captured in the Trinity River, CA during week 11. Data are from electro-fishing two 42 by 3 m lanes along both banks of four rehabilitation and control sites on the Trinity River during 1998 at a flow of approximately 14 m^3/s. N = 8. Asterisks indicate significant differences at p = 0.05.

Species	Fry	Juvenile	Total
Chinook Salmon	0.0179	-0.0011*	0.0152
Coho	-	-0.0002	-0.0002
Steelhead	0.0002	-0.0012 *	0.0075
Pacific Lamprey	-	-	0.0077
Brown Trout	-	-	0.0047
Speckled Dace	-	-	0.0004
Stickleback	-	-	0.0007
Klamath Sucker	-	-	0.0001
Green Sunfish	-	-	-0.0001

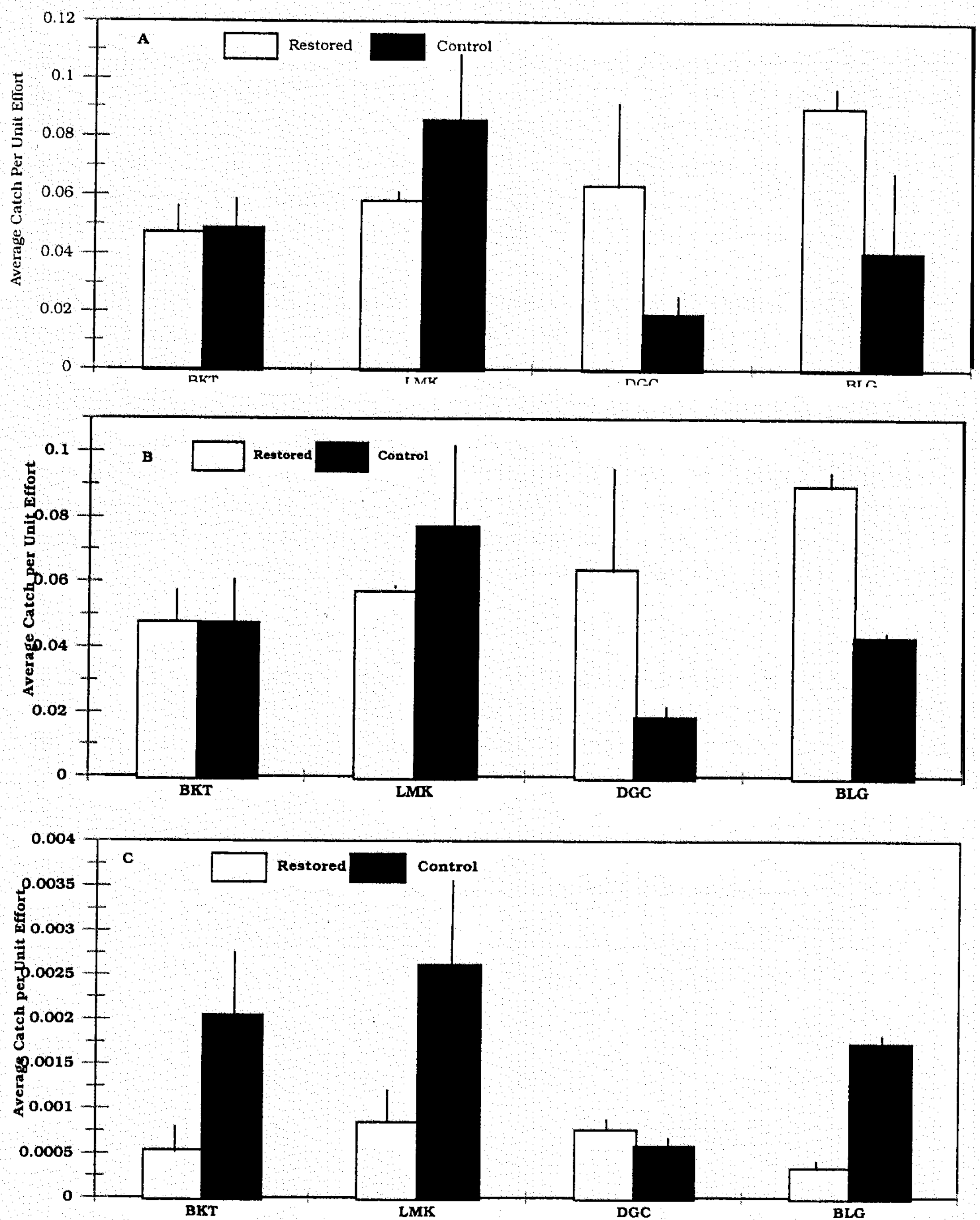

Fig. 16. Chinook salmon average catch per unit effort by site for rehabilitation and controls on the Trinity River during week 11, 1998. A). Total chinook salmon captured. B). Chinook salmon < 50 mm. C). Chinook salmon > 50 mm. Data are means, n = 2. Thin lines represent 1 SE.

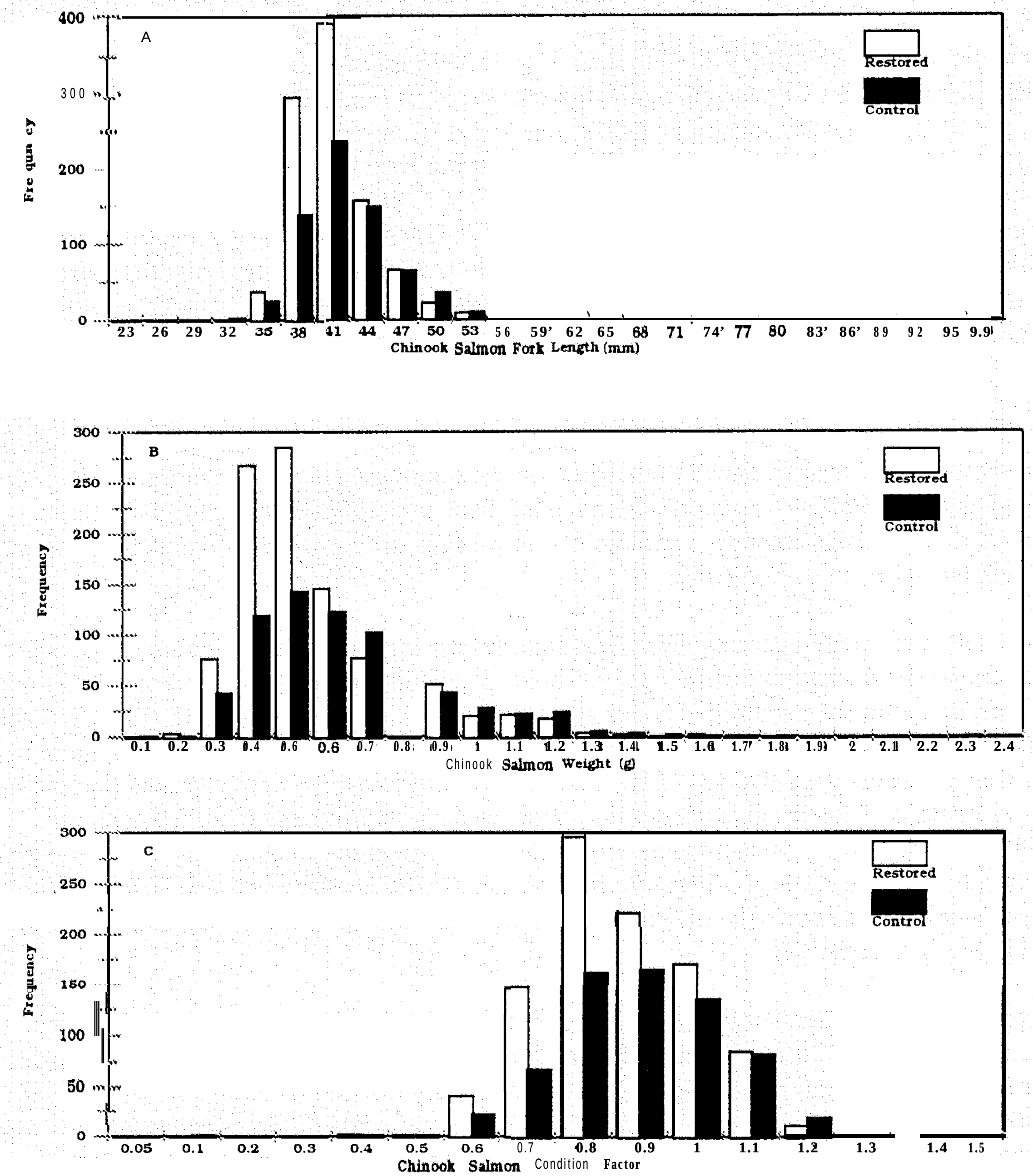

Fig. 17. Chinook salmon fork length, weight and condition factor distributions for rehabilitation and control sites in the Trinity River during week 11, 1998. A). Fork length frequency. B). Weight frequency. C. Condition factor frequency. Data are from fish collected electro-fishing 42.5 by 3 m lanes along the banks of the four rehabilitation and control sites; N = 97 1, 662.

During week 11 chinook salmon fry fork length frequencies were significantly different between rehabilitation and control sites (K-S = 4.6, $p = 0.0$). Chinook fry were significantly smaller on rehabilitation sites during week 11 (Fig. 18*a*, U = 350190, $p < 0.001$). Chinook salmon juvenile fork length frequencies were significantly different between rehabilitation and control sites (K-S = 1.5, $p < 0.02$). Chinook salmon juveniles were larger on rehabilitation sites during week 11 (Fig. 18*a*). Similarly, chinook salmon fry weights during week 11 were significantly lower at rehabilitation sites (Fig. 18*b*, U = 364058, $p < 0.0001$). Chinook salmon juvenile weights were not significantly higher at rehabilitation sites (Fig. 18*b*; U = 85, $p = 0.09$). Chinook salmon fry condition factors during week 11 were significantly lower for fish captured on rehabilitation sites (Fig. 18*c*, U = 349335, $p < 0.0001$). Juvenile chinook salmon condition factors during week 11 were not significantly different between rehabilitation and controls (Fig. 18*c*, U = 93, $p = 0.35$).

When examined by bank, 88% of chinook salmon juveniles captured at rehabilitation sites during week 11 were found along the unmodified bank. Sixty five percent of chinook salmon fry were captured on the constructed bank at rehabilitation sites during week 11. At control sites 5 1% of chinook salmon juveniles were captured on the left bank and 49% on the right. Fifty three percent of the chinook salmon fry captured at control sites during week 11 were collected on the right bank and 47% on the left bank.

Chinook salmon fry catch per unit effort was significantly higher on the constructed banks at rehabilitation sites during week 11 (Fig. 19, Table 13). Chinook salmon juvenile catch per unit effort was higher on the unmodified banks at rehabilitation sites during week 11 (Fig. 19, Table 13). Brown trout catch per unit effort was higher on the constructed bank at rehabilitation sites during week 11 (Fig. 19, Table 13). Only two brown trout juveniles were captured during week 11. Stickleback and steelhead catch per unit effort was higher on the unmodified banks at rehabilitation sites during week 11 (Fig. 19, Table 13). Only three steelhead fry were captured during week 11. There was no difference in coho salmon, Pacific lamprey, and speckled dace catch per unit effort between the constructed and unmodified banks at rehabilitation sites during week 11 (Fig. 19, Table 13).

When examined by site, chinook salmon fry catch per unit effort was not significantly different between the constructed and unmodified banks at any site (Fig. 20*a*, Table 14). However three of four sites had non-significantly higher fry catch per unit effort on the constructed bank. Chinook salmon juvenile catch per unit effort was not significantly different between constructed and unmodified banks at any site (Fig. 20*b*, Table 14). Three of the four sites showed higher catch per unit effort of chinook salmon on the unmodified banks. Brown trout catch per unit effort was significantly higher on the constructed bank at two of the rehabilitation sites (Fig. 20*c*, Table 14). There was no difference in steelhead catch per unit effort between the constructed and unmodified banks at any rehabilitation site (Fig 20*d*, Table 14). Coho salmon were only captured on the unmodified bank at the Lime Kiln rehabilitation site, thus there was a significant difference between constructed and unmodified banks at this site for this species (Table 14).

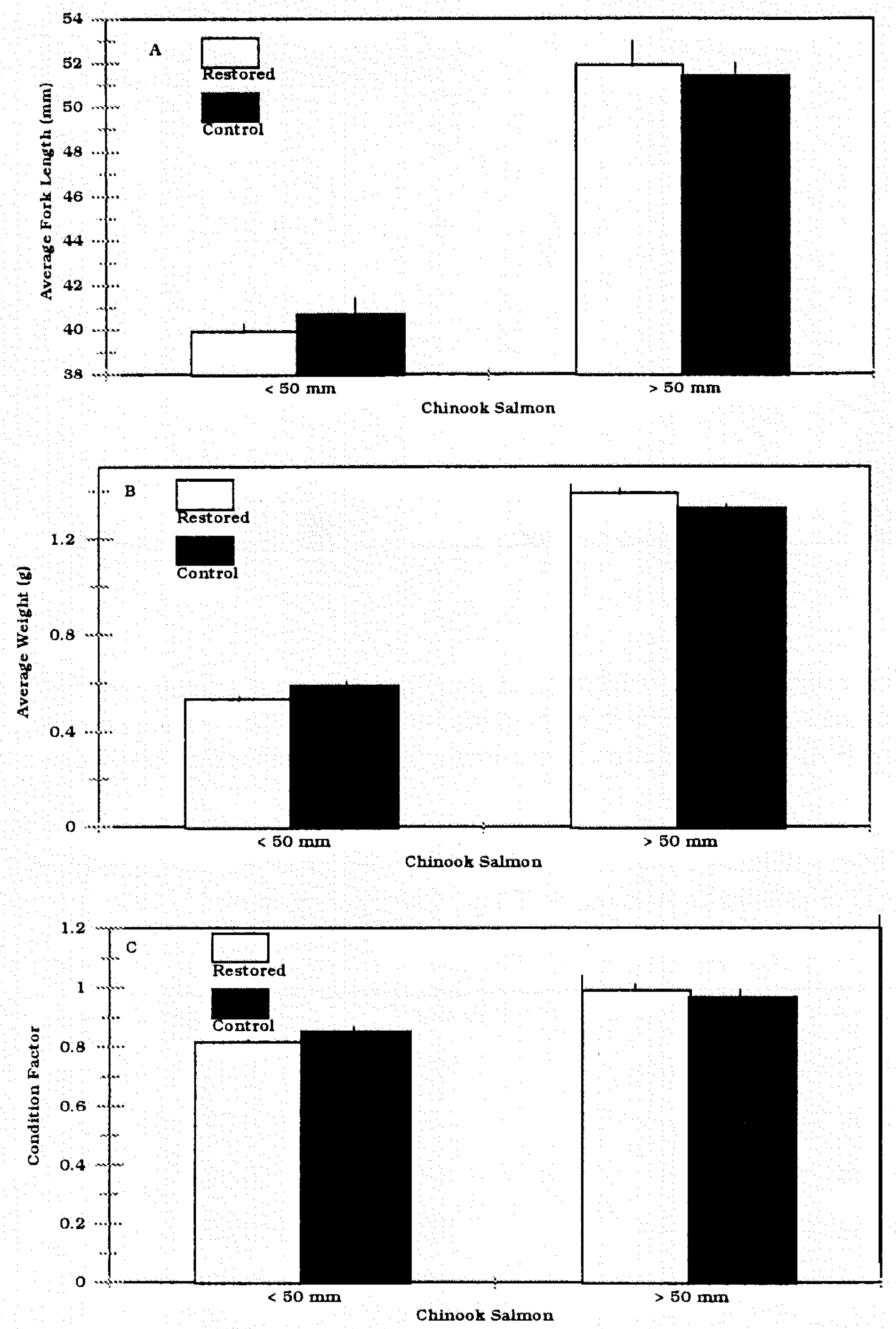

Fig. 18. Chinook salmon mean fork length, weight, and condition factor for rehabilitation and control sites on the Trinity River during week 11, 1998. 4). Fork length, B). Weight. C), Condition factor. Data are means, n = 3. Thin lines represent 1 SE.

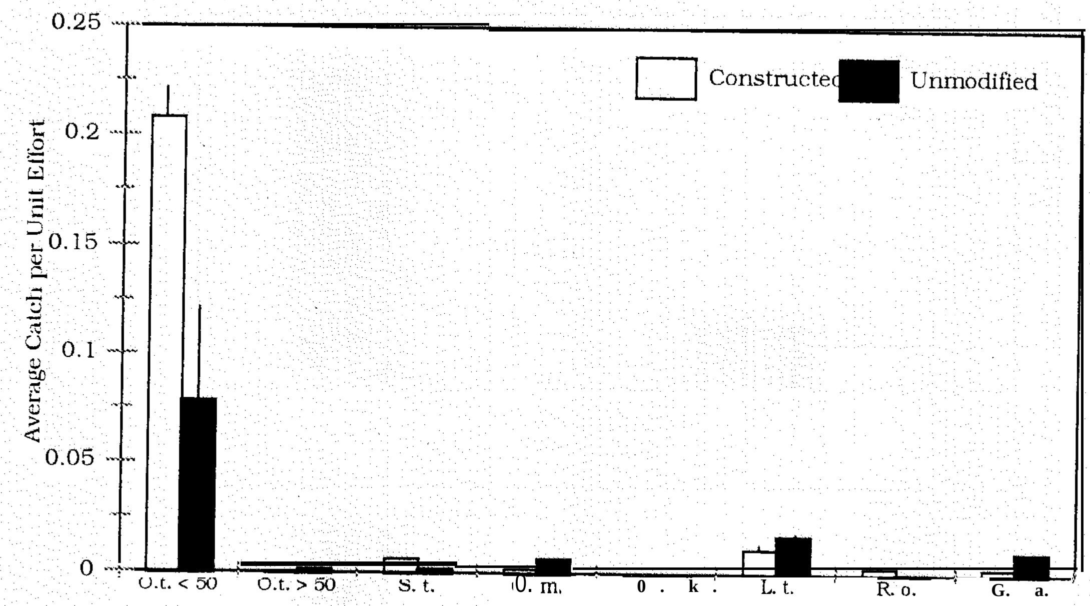

Fig. 19. Mean catch per unit effort for fish collected along the constructed and unmodified banks at rehabilitation sites in the Trinity River, CA during week 11, 1998. Data are means, n = 4. Thin lines represent 1 SE, Abbreviations along x-axis are species names (see Methods).

Table 13. Results of Mann-Whitney comparisons of catch per unit effort between constructed and unmodified banks at rehabilitation sites on the Trinity River during week 11, 1998.

	U-Value	p-Value
Chinook Salmon < 50mm	1.5	0.03
Chinook Salmon > 50mm	13	0.09
Steelhead	13	0.09
Coho Salmon	10	0.65
Brown Trout	13	0.09
Speckled Dace	5	0.20
Pacific Lamprey	10	0.65
Stickleback	13	0.09

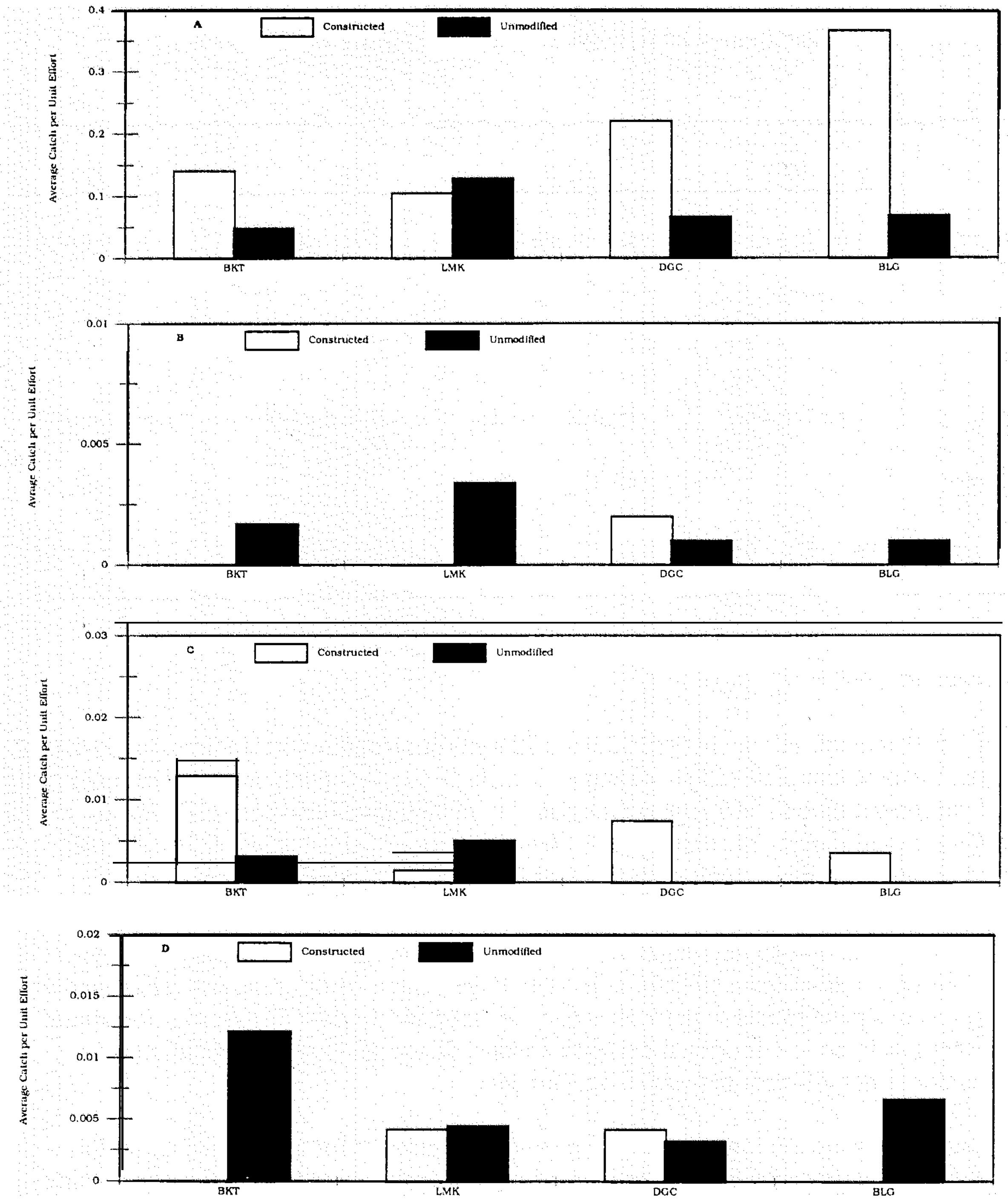

Fig. 20. Mean catch per unit effort on constructed and unmodified banks at rehabilitation sites on the Trinity River during week 11, 1998. A). Chinook salmon < 50 mm. B). Chinook salmon > 50 mm. C). Brown trout. D). Steelhead. Data are means, n = 2.

Table 14. Results of by site t-test comparisons of catch per unit effort on the constructed and unmodified banks at rehabilitation sites in the Trinity River during week 11, 1998; n = 2.

	BKT	LMK	DGC	BLG
Chinook Salmon < 50mm	t = 3.0 p= 0.08	t = 0.9, p= 0.40	t = 0.8, p= 0.50	t = 3.2, p = 0.19
Chinook Salmon > 50mm	t = 1, p= 0.50	t = 1.9, p= 0.30	t = 0.4, p= 0.70	t = 1, p = 0.5
Steelhead	t = 1.7, p= 0.33	t = 0.21, p= 0.8	t = 10.4, p= 0.06	t = 6.3, p= 0.09
Coho Salmon		t = 17, p = 0.04		
Brown Trout	t = 19.3, p= 0.003	t = 0.5, p= 0.70	t = 2.4, p= 0.80	t = 14.2, p= 0.02

Mark-Recapture 1998

A total of 2,950 chinook salmon between 32 and 72 mm fork length were captured, marked, and released during three complete (all sites sampled, weeks 9, 11, 18) and three partial samples (1 lane Bucktail rehabilitation and 1 lane at Douglas City rehabilitation and control- week 8, Douglas City rehabilitation and control-week 14, and portions of all sites- week 16). Of the 2,950 marked and released chinook salmon, 18 or 0.63% were recaptured. Eight of the 18 recaptured chinook salmon were at rehabilitation sites and half of these were using the restored bank (Table 15). Chinook salmon were found to rear between six and 49 days at rehabilitation sites and between four and 49 days at control sites. Half of the fish recaptured at rehabilitation sites were shown to rear at these sites for at least 49 days. Three-fifths of the fish recaptured at control sites were shown to rear at these sites between four and 14 days (Table 15). Recapture numbers were much too low for statistical comparisons. It appears that rearing duration for chinook salmon is not different between the treatments.

Recapture numbers were too low to calculate population estimates for any site using the Jolly-Seber method. The numbers were also much too low to calculate population estimates for any site using other methods except for the Bell Gulch site for fish marked during week 11 and recaptured during week 18. Using the Peterson method, a population estimate of 833 ± 873 chinook salmon was calculated for the Bell Gulch rehabilitation site. A population estimate of 2,548 ± 2,824 chinook salmon was calculated for the Bell Gulch control site. The confidence intervals for both sites exceed the estimates, thus they are of limited value. It is likely that the high flows encountered while sampling and between samples strongly influenced recapture results. However, it is interesting that eight fish remained within the same 42 m length of bank while river stages fluctuated more than 1 m, river width ranged from 30 to 75 m, and flows ranged from 25 to 200 m^3/s. Furthermore, these same chinook salmon remained along the bank even after flows receded to less than 100 m^3/s. At least two of the marked fish reared on the constructed bank at rehabilitation sites through the widely fluctuating flows (Table 15).

Table 15. Number of chinook salmon recaptured and rearing duration by site and bank for rehabilitation and control sites on the Trinity River during 1998. Site names are described in the text. Cons. refers to the constructed bank. Unmd. is the unmodified bank. LB is left bank. RB is right bank. Asterisk indicates data collected during habitat use verification.

Rehabilitation				Control			
Number Fish Recaptured	Rearing Duration Days	Site	Bank	Number Fish Recaptured	Rearing Duration Days	Site	Bank
2	6	LMK	BOTH	3	4	DGC	LB, RB
1	8	BKT	CONS.	1	6	LMK	LB
1	18	BLG	UNMD.	2	14	BKT	LB
1	49	LMK	CONS.	2	35*	BKT	LB
1	49	BKT	UNMD.	1	49	BLG	LB
1	49	DGC	UNMD.	1	49	LMK	LB
1	49	BLG	CONS.				

Chinook Salmon Growth Rates 1998

During week 8 chinook salmon median fork lengths were higher at control sites (Fig. 21). Statistical comparisons were not possible for week 8 due to the small sample size. Median fork lengths during week 9 were not significantly higher at control sites ($U = 11$, $p = 0.45$; Fig. 21). Median fork lengths during week 11 were not significantly higher at control sites ($U = 13$, $p = 0.11$; Fig. 21). Median fork lengths during week 18 were not significantly higher at control sites ($U = 13.5$, $p = 0.15$; Fig. 21). Growth rates were not different between rehabilitation and control sites during 1998 (Fig. 21).

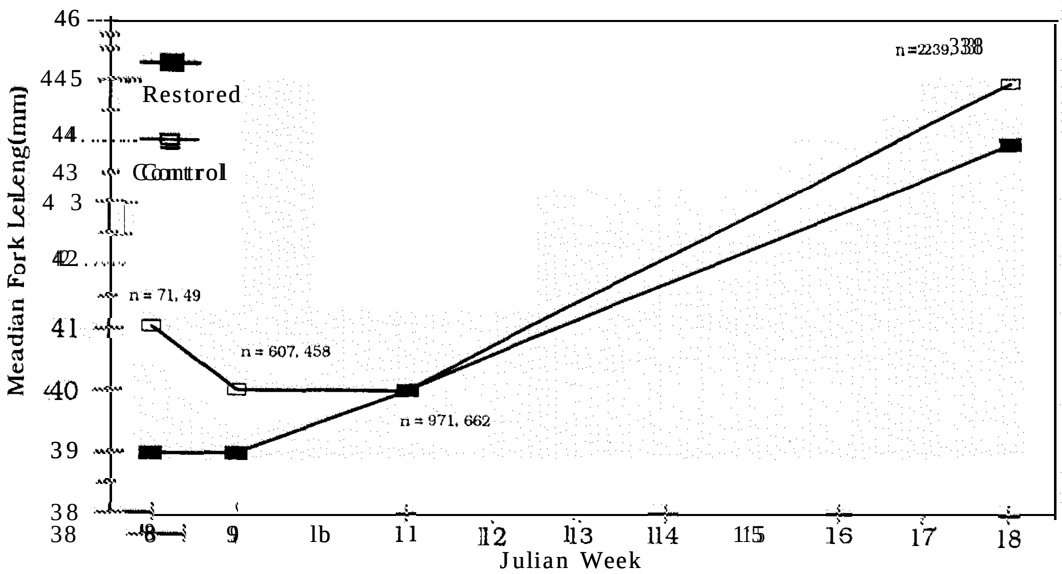

Fig. 21. Chinook salmon median fork lengths for rehabilitation and control sites on the Trinity River during 1998. Week 8 begins 18 February.

Median fork lengths of recaptured fish at rehabilitation and control sites show that fish recaptured at rehabilitation sites generally increased at the same rate for periods of less than one week while the median fork length of fish rearing for longer periods was slightly higher at rehabilitation sites (Figs. 22, 23). Two fish recaptured at rehabilitation sites after one week showed a decrease in median fork length. This is likely a result of using median fork length of the sample rather than individual fork length. The cause of an apparent increase of 9 mm in two weeks by one fish at a control site (Fig. 23) is also due to the use of median rather than individual fork lengths.

Chinook salmon specific growth rates were not significantly different between rehabilitation and control sites for any period (Table 16, Fig. 24). Calculation of growth rates between week 8 and other weeks was not possible because only one site was sampled this week. Growth was not significantly different between treatments for any period (Fig. 24, Table 16). The average specific growth rate for recaptured fish at rehabilitation sites (0.23) was not significantly different than those recaptured at controls sites (0.28) (t = -0.24 p = **0.8**).

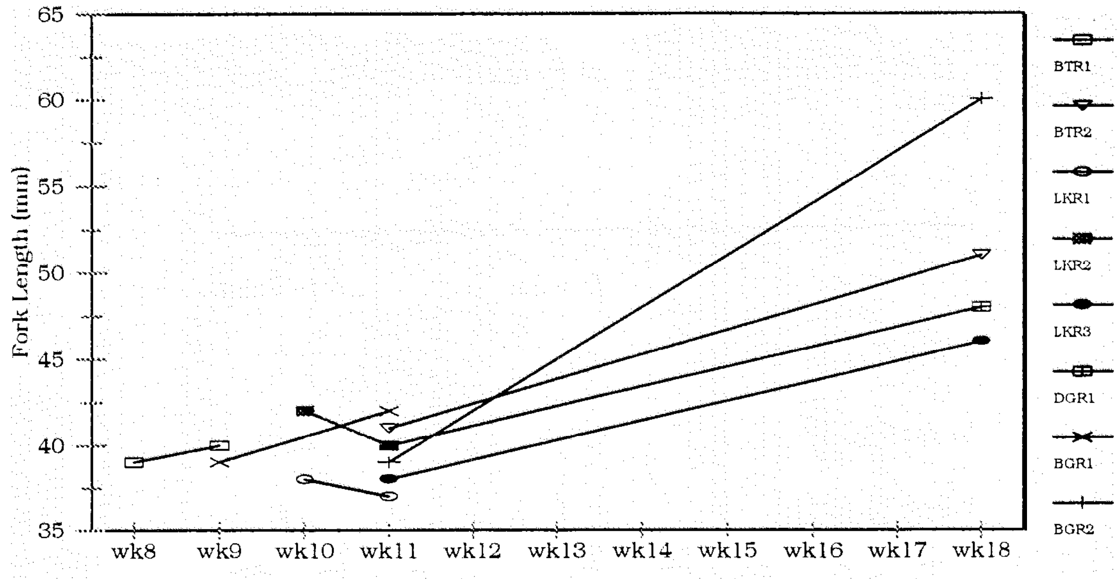

Fig. 22. Median and actual fork lengths of chinook salmon recaptured at rehabilitation sites on the Trinity River during 1998. Legend indicates the site where fish were captured.

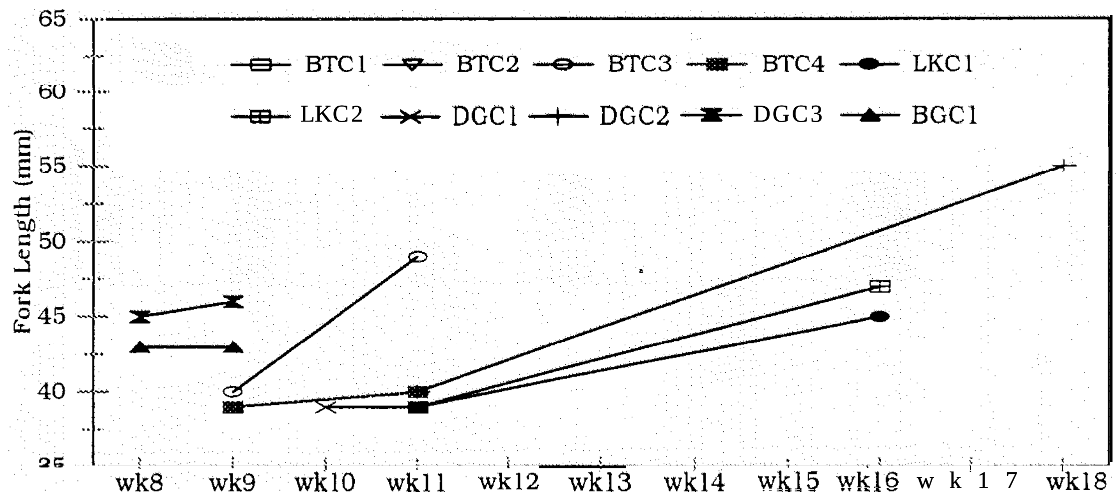

Fig. 23. Median and actual fork lengths for chinook salmon recaptured at control sites in the Trinity River during 1998. Legend indicates the site where fish were captured.

Table 16. Results of Mann-Whitney comparisons of specific growth rates of chinook salmon between rehabilitation and control sites. Data are from eleetro-fishing two 42.5 by 3 m lanes along both banks, n = 4.

	U-value	p-Value
Week9 to 11	9.5	0.77
Week9 to 18	9.0	0.89
Week 11 to 18	9 .0	0.88

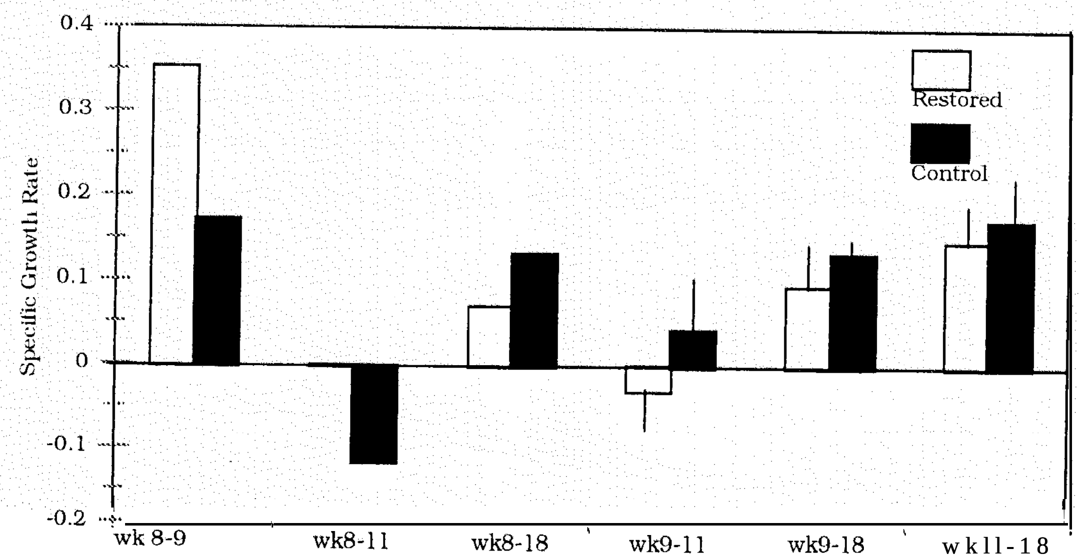

Fig. 24. Specific growth rates for chinook salmon collected along the banks of four rehabilitation and control sites in the Trinity River during 1998. Thin lines represent 1 SE. Sample sizes to estimate median fork length for each rehabilitation and control site are shown in Fig. 2 1.

Fish Species Diversity

Nine fish species were collected during week 11 of 1998 (Table 9). Total fish species diversity was not significantly higher at rehabilitation sites during week 11 (Table 17; t = 0.38, p = 0.72). With exotic (non-indigenous) fish species removed from the analysis, diversity was not significantly different between rehabilitation and controls (Table 17; t = -0.36, p = 0.74). Fish species diversity was not compared for sample week 8 because not all sites were sampled that week. Species diversity for rehabilitation and control sites during weeks 9 and 18 were similar to those of week 11. Fish species diversity was not significantly different between rehabilitation and controls during week 9 (t = -0.38, p = 0.70). With exotics removed from the analysis, species diversity was not significantly different (t = -0.02, p = 0.998). Similarly, fish species diversity was not significantly different between rehabilitation and controls during week 18 (t = -0.27, p = 0.80). With exotics removed from the analysis, species diversity was not significantly different (t = -0.64, p = 0.50). Fish species diversity in the existing channel *(rehabilitation and control sites combined)* was not significantly different than the control sites during week 11 (t = 0.51, p = 0.62). With exotics excluded there was no difference in fish species diversity between the existing channel and control sites (t = 0.08, p = 0.93).

Table 17. Species diversity for rehabilitation and control sites on the Trinity River during week 11, 1998. None were significant at p = 0.05.

	All Species		Excluding Exotics	
Site	Rehabilitation	Control	Rehabilitation	Control
BKT	0.3474	0.3244	0.2546	0.3039
LMK	0.3693	0.2953	0.2189	0.1471
DGC	0.4030	0.4134	0.2421	0.3718
BLG	0.2078	0.2014	0.2004	0.1730

Habitat Diversity

Habitat diversity was not significantly different between rehabilitation and control sites at any of the flows measured (Table 18). Total habitat diversity (all habitat types considered) was not significantly higher at rehabilitation sites for three flows. At the two higher flows habitat diversity was not significantly higher at rehabilitation sites for all species and life stages (Table 18). At the lowest flow habitat diversity was generally not significantly higher at control sites. The general trend is an increase in habitat diversity as flows increase at rehabilitation sites compared to control sites (Table 18).

Habitat diversity in the existing channel (rehabilitation *and controls combined*) is generally higher than at control sites (Table 19). Total habitat diversity was significantly higher at rehabilitation sites at the 9.57 m^3/s dam release. Chinook salmon fry and juvenile habitat diversity was significantly higher at the 76.5 and 145.8 m^3/s dam releases (Table 19). Steelhead fry and juvenile habitat diversity also demonstrates this trend. Habitat diversity for all species and life stages was higher in the existing channel for all flows.

Table 18. Means, t-tests, and p-values of life stage and total habitat diversity indices (H') from rehabilitation and control sites in the Trinity River for four Lewiston Dam releases. Asterisk indicates that *O. t.* fry and *O. m.* fry habitat for calculating diversity is the same (Appendix B). Data are means, n = 4. Numbers in parenthesis are standard errors, See methods for abbreviation definitions.

Discharge m^3/s	Species	Life Stage	Rehabilitation	Control	*t*	*p*
9.57	0. *t.*	Fry*	0.839 (0.10)	0.874 (0.08)	-0.27	0.79
		Juvenile	0.824 (0. 10)	0.678 (0.14)	0.83	0.44
	0. *m.*	Juvenile	0.767 (0.11)	0.785 (0.04)	-0.16	0.88
	O. k.	Fry	0.846 (0.06)	0.743 (0.05)	1.22	0.26
		Juvenile	0.705 (0.05)	0.78 1 (0.08)	-0.58	0.58
	Total Diversity		0.586 (.07)	0.489 (0.06)	1.08	0.32
43.9	0 . *t.*	Fry*	0.798 (0.12)	0.735 (0.02)	0.51	0.63
		Juvenile	0.708 (0.15)	0.716 (0.03)	-0.06	0.95
	0. *m.*	Juvenile	0.656 (0.15)	0.696 (0.03)	-0.27	0.8
	0. *k.*	Fry	0.685 (0.10)	0.683 (0.04)	0.01	0.99
		Juvenile	0.759 (0.07)	0.746 (0.06)	0.13	0.89
	Total Diversity		0.457 (0.12)	0.443 (0.05)	0.11	0.92
76.5	0. *t.*	Fry*	0.828 (0.06)	0.720 (0.10)	0.94	0.38
		Juvenile	0.808 (0.07)	0.693 (0.04)	1.48	0.09
	0. *m.*	Juvenile	0.780 (0.05)	0.724 (0.01)	1.01	0.35
	0. *k.*	Fry	0.817 (0.03)	0.623 (0.01)	1.71	0.07
		Juvenile	0.785 (0.07)	0.702 (0.04)	1.01	0.35
	Total Diversity		0.48 1 (0.01)	0.443 (0.08)	0.38	0.72
145.8	0. *t.*	Fry*	0.890 (0.09)	0.681 (0.11)	1.46	0.09
		Juvenile	0.860 (0.09)	0.714 (0.11)	1.03	0.34
	0. *m.*	Juvenile	0.780 (0.13)	0.626 (0.17)	0.71	0.5
	0. *k.*	Fry	0.828 (0.03)	0.641 (0.14)	1.3	0.24
		Juvenile	0.785 (0.07)	0.648 (0.16)	0.77	0.47
	Total Diversity		0.523 (0.01)	0.582 (0.04)	-0.59	0.57

Table 19. Means, t-tests, andp-values of life stage and total habitat diversity indices (H') from the existing channel (rehabilitation and control sites combined) and control sites on the Trinity

Table 19. Means, t-tests, and p-values of life stage and total habitat diversity indices (H') from the existing channel (rehabilitation and control sites combined) and control sites on the Trinity River for four Lewiston Dam releases. Asterisk indicates that *O. t.* fry and *O. m.* fry habitat for calculating diversity is the same (Appendix B). Data are means, n = 4. Numbers in parenthesis are standard errors. See methods for abbreviation definitions.

Discharge m^3/s	Species	Life Stage	Existing Channel	Control	t	p
9.57	*O. t.*	Fry*	0.958 (0.07)	0.574 (0.08)	0.75	0.45
		Juvenile	0.932 (0.09)	0.675 (0.14)	1.49	0.09
	O. m.	Juvenile	0.913 (0.09)	0.755 (0.03)	1.35	0.22
	O. k.	Fry	0.907 (0.08)	0.743 (0.05)	1.65	0.08
		Juvenile	0.839 (0.07)	0.751 (0.08)	0.53	0.61
	Total Diversity		0.656 (0.06)	0.459 (0.06)	1.97	0.045
43.9	*O. t.*	Fry*	0.882 (0.02)	0.735 (0.01)	1.8	0.06
		Juvenile	0.818 (0.13)	0.716 (0.03)	0.76	0.47
	O. m.	Juvenile	0.774 (0.13)	0.696 (0.03)	0.6	0.57
	O. k.	Fry	0.820 (0.08)	0.683 (0.04)	1.45	0.09
		Juvenile	0.902 (0.04)	0.707, (0.03)	1.82	0.06
	Total Diversity		0.546 (0.03)	0.443 (0.05)	1.6	0.08
76.5	*O. t.*	Fry*	0.947 (0.05)	0.720 (0.10)	1.99	0.046
		Juvenile	0.879 (0.03)	0.693 (0.04)	3.29	0.03
	O. m.	Juvenile	0.844 (0.02)	0.724 (0.01)	3.88	0.01
	O. k.	Fry	0.855 (0.06)	0.623 (0.11)	1.9	0.06
		Juvenile	0.810 (0.04)	0.702 (0.03)	1.52	0.06
	Total Diversity		0.507 (0.07)	0.443 (0.08)	0.71	0.35
145.8	*O. t.*	Fry*	0.990 (0.04)	0.681 (0.11)	2.56	0.04
		Juvenile	0.950 (0.06)	0.714 (0.11)	1.93	0.05
	O. m.	Juvenile	0.889 (0.03)	0.626 (0.17)	1.43	0.20
	O. k.	Fry	0.915 (0.04)	0.641 (0.13)	1.88	0.07
		Juvenile	0.545 (0.09)	0.648 (0.16)	1.05	0.33
	Total Diversity		0.707 (0.08)	0.582 (0.04)	1.33	0.11

DISCUSSION

Although river restoration must address the entire natural-cultural ecosystem (Independent Scientific Group 1999), channel rehabilitation, as employed in the Trinity River, may assist in developing a mosaic of complex and interconnected habitats. The results of this study suggest that rehabilitation projects on the mainstem Trinity River have resulted in increased habitat and increased habitat diversity with increased flows. Fish use was increased as a result of rehabilitation. Specific results suggesting rehabilitation increases habitat diversity are evidenced by both physical and biotic data. The results of the hydraulic comparisons show the river to be w'ider and have more diverse depth and velocity profiles across the channel at rehabilitation sites. Bed profiles across the river also show increased complexity at rehabilitation sites over the U-shaped channel at control sites. McBain and Trush (1997) found that rehabilitation increased bed profile diversity and suggest it increased channel complexity.

The WUA results show significant differences between rehabilitation and control sites with increased flow for some species and life stages, especially for chinook salmon and steelhead fry, suggesting a more diverse river. Channel rehabilitation was originally intended to increase rearing habitat, especially for fry (USFWS 1994, 1997). The results of this study, contrary to Gallagher (1995), indicate that fry rearing habitat has increased as a result of rehabilitation. This study differed from Gallagher (1995) by using actual, not modeled, hydraulic data to calculate WUA, compared rehabilitation sites to control sites (sites with a vegetation encroached berm.) rather than comparing between banks at rehabilitation sites, and compared data for flows within the range of flows the sites were intended to increase rearing habitat. This study differed from USFWS (1997) in that the design allowed statistical comparisons. Furthermore this study included habitat diversity and more of the species and life stages of fish found in the river.

Hampton (1988) found a significant relationship between chinook salmon density and WUA at the cell level in the Trinity River. Gallagher (unpublished manuscript) found a significant correlation between WUA and chinook salmon density at the mesohabitat level in the Trinity River. These validations of WUA (an indicator of fish habitat) in the Trinity River further strengthen the use of this index to demonstrate and examine changes in salmonid habitat resulting from channel rehabilitation. The trends in fish capture over two seasons between rehabilitation and control sites mirroring WUA predictions for these sites also support the idea that a rehabilitated channel is more diverse (Figs. 4*a*, 6, 19). The development and implementation of two-dimensional modeling (Stefler and Sandlin 1998, Leclerc et al. 1995) should improve flow habitat modeling for monitoring in the Trinity River.

The significant differences in fork length and condition factors for fry and juvenile chinook salmon between rehabilitation and control sites suggests a more diverse habitat at rehabilitation sites. Chinook salmon fry were significantly smaller and juveniles larger at rehabilitation sites during 1998 suggesting more habitat diversity (i.e. greater niche breadth) as a result of channel rehabilitation. The absence of significant differences during 1997 may be due to smaller sample size as only one lane was sampled during 1997. Fork length distributions for steelhead were not significantly different both years. Steelhead fork lengths were significantly different between rehabilitation and controls in 1997 but not in 1998. This is probably due to the difference in the timing of sampling. There was no difference in the number of out migrating steelhead fry between 1997 and 1998 (J. Craig personal communication 1999). Therefore the differences between the two years for steelhead is not due to differences in emigration run size. In 1997 sampling occurred during week 16 while in 1998 sampling was conducted during week 11. It is likely that the 1998 sampling was too early to detect large numbers of small steelhead, in addition many of the larger steelhead captured during 1998 were of hatchery origin. Chinook salmon were larger on the unmodified bank at rehabilitation sites during both years. At control sites the percentage of larger chinook salmon was equal on both banks. This result also suggests a wider niche breadth (habitat diversity) as a result of rehabilitation. Similarly, significantly more chinook salmon fry were found on the constructed bank of rehabilitation sites during week 11, 1998.

Comparison of fish species diversity did not show rehabilitation sites to have more diverse habitat. This is likely a result of too small a sample size or of using only fish species rather than all aquatic species to calculate diversity indices. The non-significant trend in catch over two years is more chinook and steelhead fry at rehabilitation sites. In addition, the existing channel *(rehabilitation* and *control site data combined)* versus control site diversity comparisons by species and life stage for chinook and coho salmon and steelhead show more diverse habitat with increasing flows. This type of channel rehabilitation appears to increase habitat diversity.

Both physical and biotic results of this study suggest that rehabilitation increased fish habitat and fish use. Rehabilitation significantly increased the width of the river, especially as flows increase. The WUA at rehabilitation sites was significantly higher for some species and life stages and this trend became more apparent as flows increased. Because WUA and chinook salmon density is significantly related in the Trinity River (Hampton 1988, Gallagher unpublished), increases in WUA indicate potential increases in total fish numbers due to increased habitat capacity. In addition, catch per unit effort and WUA prediction trends were similar over two years. For instance, significantly more chinook fry were captured at rehabilitation sites and more juveniles were captured at control sites during week 11, 1998. Significantly more chinook salmon fry were captured at rehabilitation sites during 1997. This follows the WUA pattern for this flow (Fig. 4*a*). The results of total catch (1997), catch per unit effort (1998) and WUA analysis using Equation 3 show an overall increase in habitat and abundance for some species and life stages results from rehabilitation. These differences are maintained with increased flow. The USFWS (1997) suggested that WUA changes with changes in flow were less dramatic at rehabilitation sites as compared to non-rehabilitated areas, The results presented here (Fig. 4) support this hypothesis. The total area and diversity of habitats increases with increased flow in the existing channel.

Although the recapture rate during the 1998 branding survey was low (0.6%), we documented chinook salmon rearing in the Trinity River for at least 49 days. Large changes in flow during that period did not induce the few recaptured individuals to migrate. This information coupled with the increase in WUA and habitat diversity due to rehabilitation as flows increases, adds to the idea that fish habitat and instream populations may benefit from this type of rehabilitation. Flow variation during the rearing season may not impact fish rearing at rehabilitation sites as much as at control sites due to the increased stranding potential at control sites. Large flow fluctuations over a short duration may increase stranding, especially at sites with potential back water areas.

The catch per unit effort data over two years and the analysis presented herein suggest that fish use rehabilitation sites and that the use of these sites is greater than at control areas. Electro-fishing is a selective sampling tool and efficiency diminishes with increased depth. Because control sites were generally deeper than rehabilitation sites the results could , in part, be due to sampling gear. The idea that electro-fishing is easier at rehabilitation sites and therefore captures were higher is refuted by the bank by bank comparisons at rehabilitation sites. Captures along both banks at rehabilitation and control sites was variable. During both years, some sites had higher captures on the unmodified bank suggesting capturing fish along the constructed bank is not necessarily easier. Microhabitats used by, and catch per unit effort of, brown trout and coho salmon juveniles are more common along the unmodified banks at rehabilitation sites and at control sites suggesting that ease of sampling is not the primary factor affecting their collection. Some control sites, during both years, had higher captures than their corresponding rehabilitation sites adding evidence contrary to the idea that sampling is easier along constructed banks. During week 18 of 1998, more fish were captured at control sites (Figs. 14, 15). This is likely due to larger fish being present later in the year and the ability of larger fish to use habitat with higher velocities. However, during week 18 the Lewiston Dam release was greater than 100 m^3/s and much of the riparian berm along the river was inundated. At this point rearing habitat is no longer limited in the Trinity River (USFWS 1997, 1994). Fish may be using these areas more as they potentially provide greater terrestrial invertebrate fall (i.e. food) along with a greater variety of flooded back water (low velocity) habitats. However, due to the channel morphology in areas with a riparian encroached berm, stranding risk may reduce the benefits of this inundated habitat.

Our cold branding technique worked well. Yet, recaptures numbers were too low to calculate reliable population estimates. This may be a result of the study being conducted during a year with some very high stream flows which varied dramatically during the study period. It may also be due to small sample size. Brands were retained for the entire period and mortality was low. However, the results of our pen rearing test of mortality showed a reduction in growth rate that may be related to stress due to the procedure. The pen had a fine mesh (5 mm) and was placed in a low velocity (0.1 m/s) area which may have limited food input and therefore fish growth. High storm flows curtailed the pen monitoring earlier than anticipated and we were unable to follow long term survival. However, chinook salmon branded at the Lewiston hatchery survived with recognizable marks for more than two months. Everest and Edmundson (1967) used cold branding to monitor young of the year chinook salmon and steelhead. They marked fish between 37 and 18.5 mm with double digit brands and were able to identify individuals under water for at least one month. Maslin et al. (1996a, 1996b) used freeze branding for mark and recapture studies to determine non-natal rearing of chinook salmon in ephemeral tributaries to the Sacramento River. Moore (1997) also used this technique in her study of chinook salmon rearing. Demko and Cramer (1995) used freeze branding for down stream migration studies of chinook salmon in the Stanislaus River. All of the above researchers were able to mark and recapture young of the year salmon. We were also able to use this technique, however unanticipated high storm flows decreased our recapture sampling efficiency and may have induced fish to move. In one instance we documented fish moving downstream directly after return to the river following marking. This also may have affected our recaptures. Young-of-the-year chinook salmon constantly emigrate (Joe Polos Pers. Corn) which may have further decreased recapture efficiency. It appears that fish were sensitive to how they were returned to the river. If this technique is employed in the future, standardized return procedures should be developed that include slow release from holding buckets in slow moving slightly turbid water.

Fausch (1984) and Chapman and Bjorn (1969) suggest that salmonids distribute in streams in microhabitats that maximize energetic profits. Fausch (1984) found that potential profit was a good predictor of specific growth rate for salmonids. One potential affect of channel rehabilitation is increase habitat diversity which could result in growth rate differences between rehabilitation and controls. These results suggest no difference in specific growth rate between treatments. In fact, growth appears to be lower between sample dates at rehabilitation sites than at controls. This is likely a result of using median fork lengths of all captured fish to calculate growth rather than individual fish. This was not possible due to the difficulty of individually marking small fish and the low recapture rate. Rehabilitation sites had significantly more fry than controls so that growth rates are confounded by large numbers of small fish at rehabilitation sites and large numbers of larger fish at controls. In addition immigration and emigration along with colonization of available habitat at rehabilitation sites makes growth comparisons over time more difficult. Perhaps examining growth in the existing channel versus control sites would prove interesting. This is not possible at this time. A better indication of growth increases as a result of rehabilitation might be detectable from downstream trapping or survival to adults. This deserves further consideration.

By coupling rehabilitation to variable flows it may be possible to more closely mimic the complex and diverse habitat conditions and habitat mosaics under which these species evolved. Hill and Platts (1998) used passive restoration (changes in flow and riparian structure) to rehabilitate and reconnect degraded habitat in the Owens River. Rowe et al., (1989) increased salmon rearing habitat by reconnecting off channel ponds to the main channel. A suite of recent theoretical papers (Poff et al. 1997, Richter et al. 1997, Stanford et al 1996, Ligon et al. 1995, and Ward and Stanford 1995) emphasize the need to reestablish the dynamic nature of alluvial rivers including variable flows. These works further suggest this will increase bioproduction and biodiversity by increasing habitat diversity and complexity. The results presented here support the notion that rehabilitation, as employed in the Trinity River, influences habitat diversity which may influence bioproduction.

RECOMMENDATIONS

Long term adaptive management which includes realistic testable hypotheses and objectives as suggested by USFWS and Hoopa Valley Tribe (1999) needs to be developed. Agency commitment to the long term is absolutely necessary as part of any adaptive management plan. Long term monitoring should utilize the methodologies and results presented here. for future planning. Habitat diversity comparisons using the habitat typing system we developed should be expanded to include more species and life stages of fish found in the river. Other aquatic and terrestrial/riparian species should be included as well. This method should be further standardized and a protocol developed to implement it on a quarterly basis. Part of the further development of this technique should be a standardized data analysis software system This could be developed in a GIS format which could be used to detect significant changes. The use of WUA and hydraulic modeling should be continued. Two dimensional modeling could be coupled with existing model data to document baseline conditions as well as predict how flow management and habitat modification options effect habitat (Gallagher 1999). Habitat suitability criteria for other species and life stages, including cover and adjacent velocity (for aquatic species) needs to be incorporated into future modeling. Adjacent velocity data can be used to further examine if habitat diversity has increased by testing the idea that more habitats with higher velocity diversity has been created by rehabilitation. Electrofishing along banks can be continued to determine if the rehabilitation sites are being used and if the use is still greater than at controls. Loss of differences over time could be a signal that rehabilitation-site maintenance is needed. If electrofishing is no longer used, relationships between this technique and snorkeling should be developed. It should be noted that this study intended to use snorkeling rather than electrofishing but two years of high river turbidity did not allow the use of this technique. A full comparison of species diversity between rehabilitation and control sites should be conducted. Channel rehabilitation in the Trinity River appears to be working to increase chinook salmon and steelhead fry rearing habitat and habitat diversity. However, without a long term commitment to monitoring and quantitative testing of specific hypotheses (adaptive management) the benefits and contribution of rehabilitation to ecosystem integrity in the Trinity River will remain unknown.

ACKNOWLEDGMENTS

Many people assisted with this project. I thank: Charlie Chamberlin, Cindy Glase, Jay Glase, Ann Gray, Tracy Mcculloch, Rick Quihillalt, Polly Taylor, Jack Williamson, and Paul Zedonis of the US Fish and Wildlife Service, Arcata, CA; Ron Smith with the California Department of Fish and Game, Weaverville, CA; and Troy Branham, Bonnie Jackson, Rocky Jones, and Amose Pole of the Hoopa Valley Tribe; and Dan Westermeyer, resident of Weaverville, CA for assistance with field data collection. Scott McBain and Becky McBain of McBain and Trush Arcata, CA assisted with total station training, planform maps, and habitat delineation study design. Jack Williamson and Teri Moore with the California Department of Fish and Game in Weaverville, CA assisted with cold branding techniques. Gary Ramsden at the Lewiston Hatchery provided test fish and space to test the cold branding technique. Cris Jones with Redwood National Park assisted with GIS habitat analysis. Robert Franklin with the Hoopa Valley Tribe and Bill Trush of McBain and Trush, Arcata, CA provided critical evaluation of some aspects of the study design. Jay Glase and Mark Gard of the USFWS in Sacramento assisted with study design. Dr. Colin Gallagher at Clemson University, SC assisted with statistical analysis and study design. John Bartholow with the U.S. Geologic Survey in Fort Collins, CO; Mark Gard; Jay Glase; Andrew Hamilton with the USFWS in Sacramento, CA; Joe Polos; Rick Quihillalt; and Paul Zedonis provided helpful comments on earlier drafts of this report. This project was funded by the Trinity River rehabilitation program Public Law 98-541.

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PERSONAL COMMUNICATIONS

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Paul Zedonis. July 1998. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata. CA.

APPENDIX A

Aerial Photographs of Rehabilitation and Control Sites on the Trinity River, California 1997.

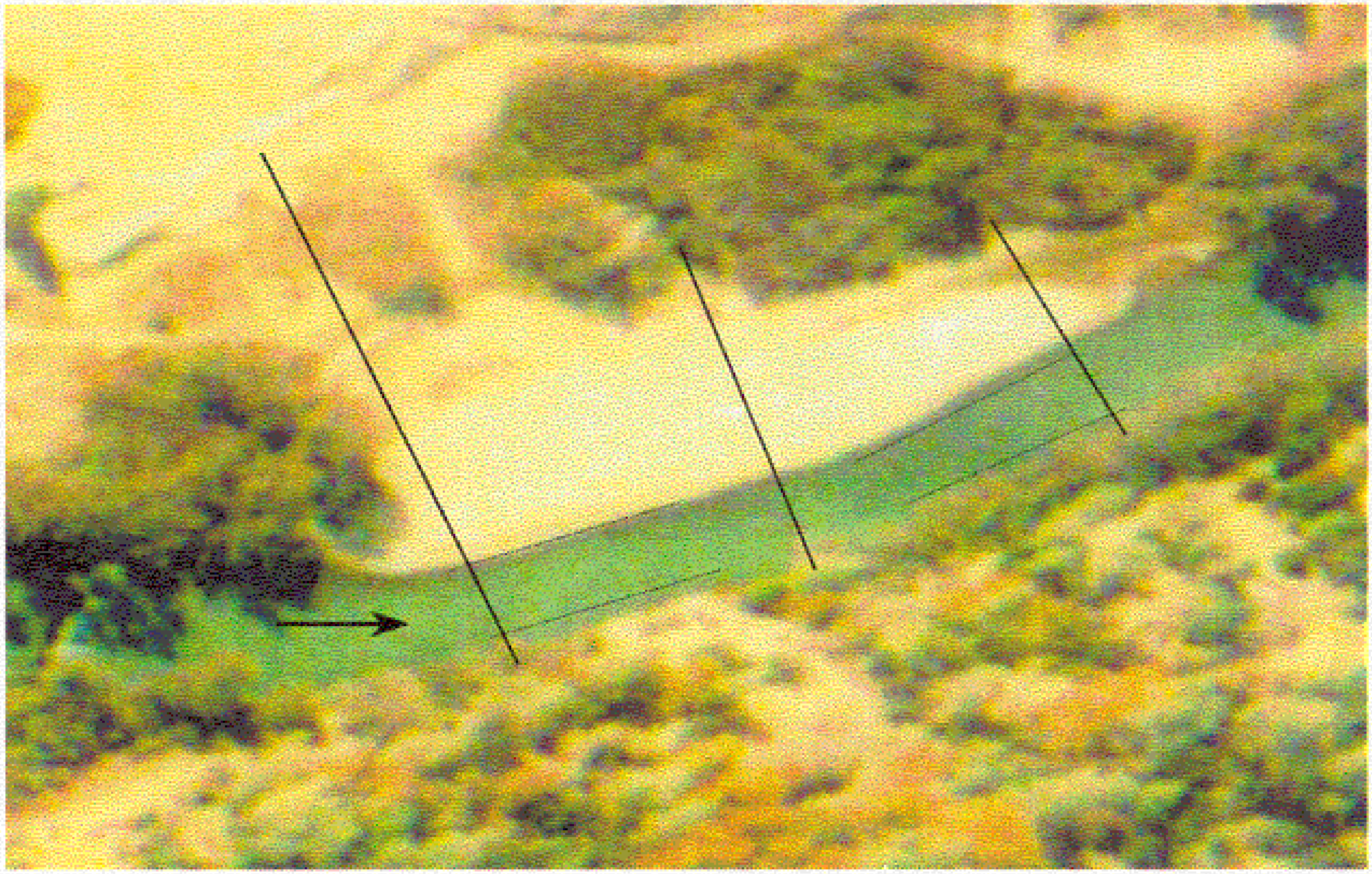


Fig. 1 Buck Tail restoration site on the Trinity River, CA. Thin lines are hydraulic transects. Dotted lines indicate fish sampling areas. Arrow indicates flow direction. Flow is approximately 12.6 m^3/s.

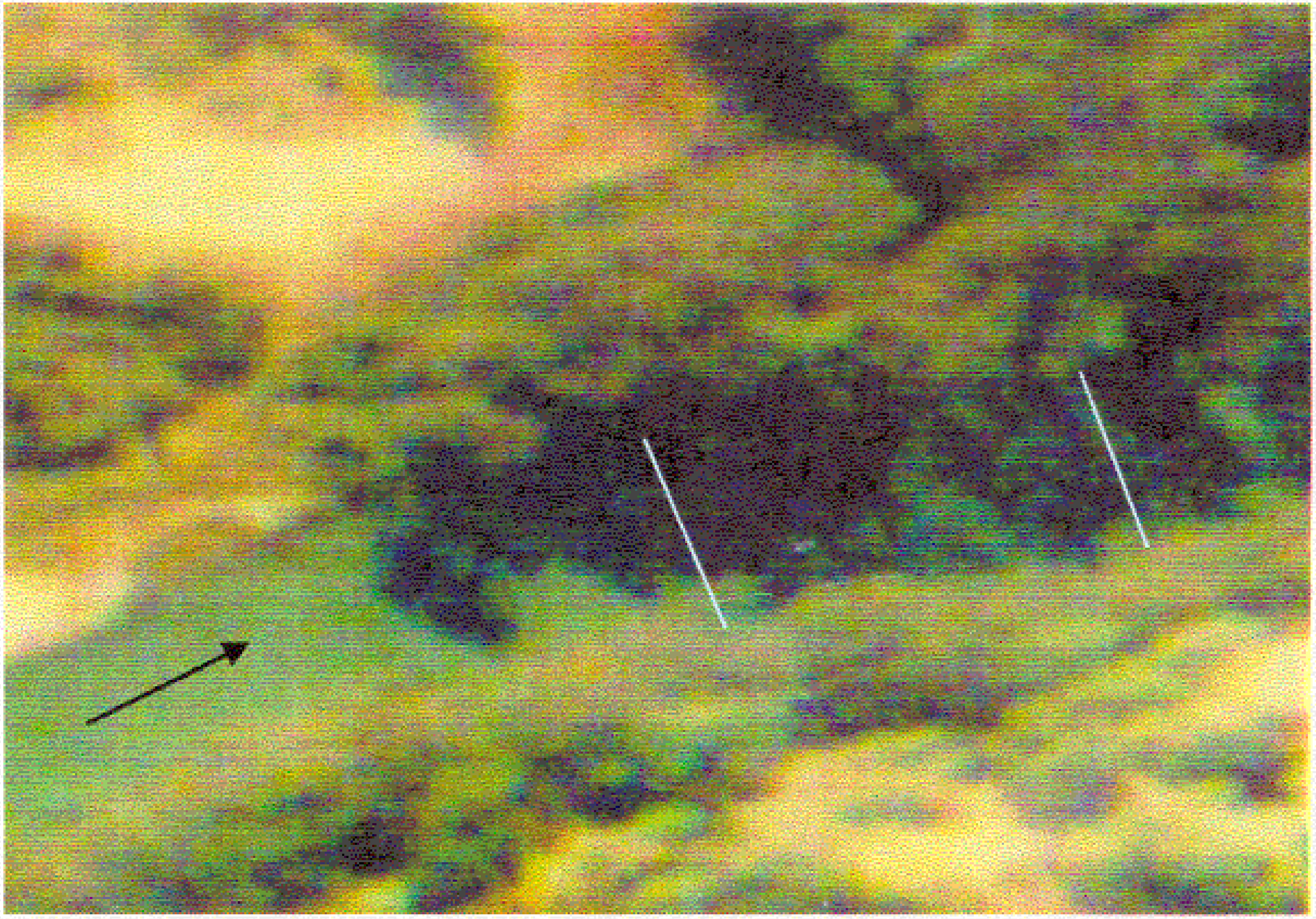
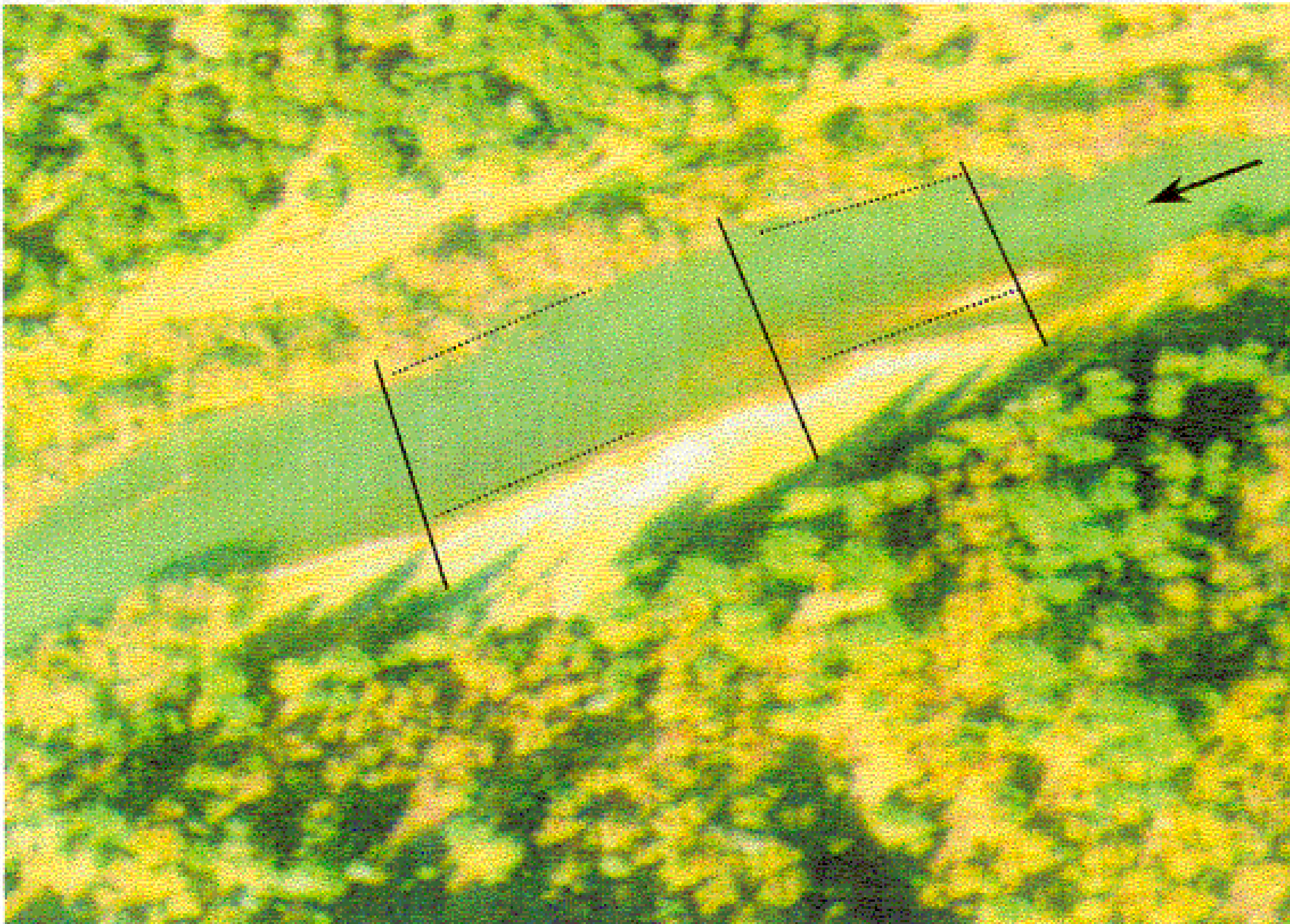


Fig. 2. Buck Tail control site on the Trinity River, CA. Thin lines are hydraulic transects. Dashed lines indicate fish sampling areas. Arrow shows flow direction. Flow is approximately 12.6 ^{3}m/s.



Fi.g 3. Lime Kiln restoration site on the Trinity River, CA. Thin lines are hydraulic transect locations. Dashed lines show locations of fish sampling lanes. Arrow indicates flow direction. Discharge is approximately 12.6 m^3/s.

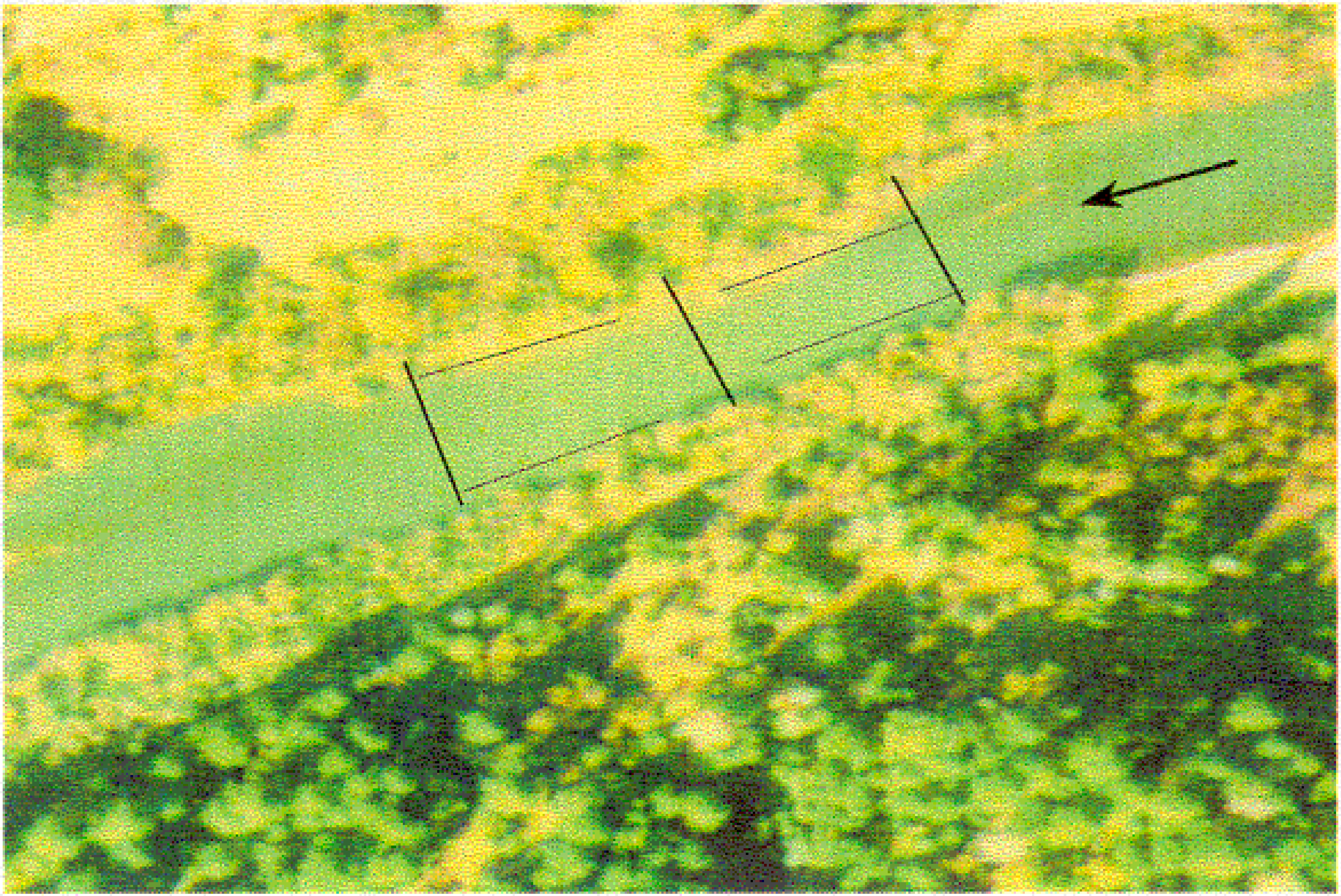


Fig. 4. Lime Kiln control site on the Trinity River, CA. Thin lines show hydraulic transect locations. Dashed lines indicate fish sampling lane locations. Arrow shows flow direction. Discharge is approximately 12.6 m^3/s.

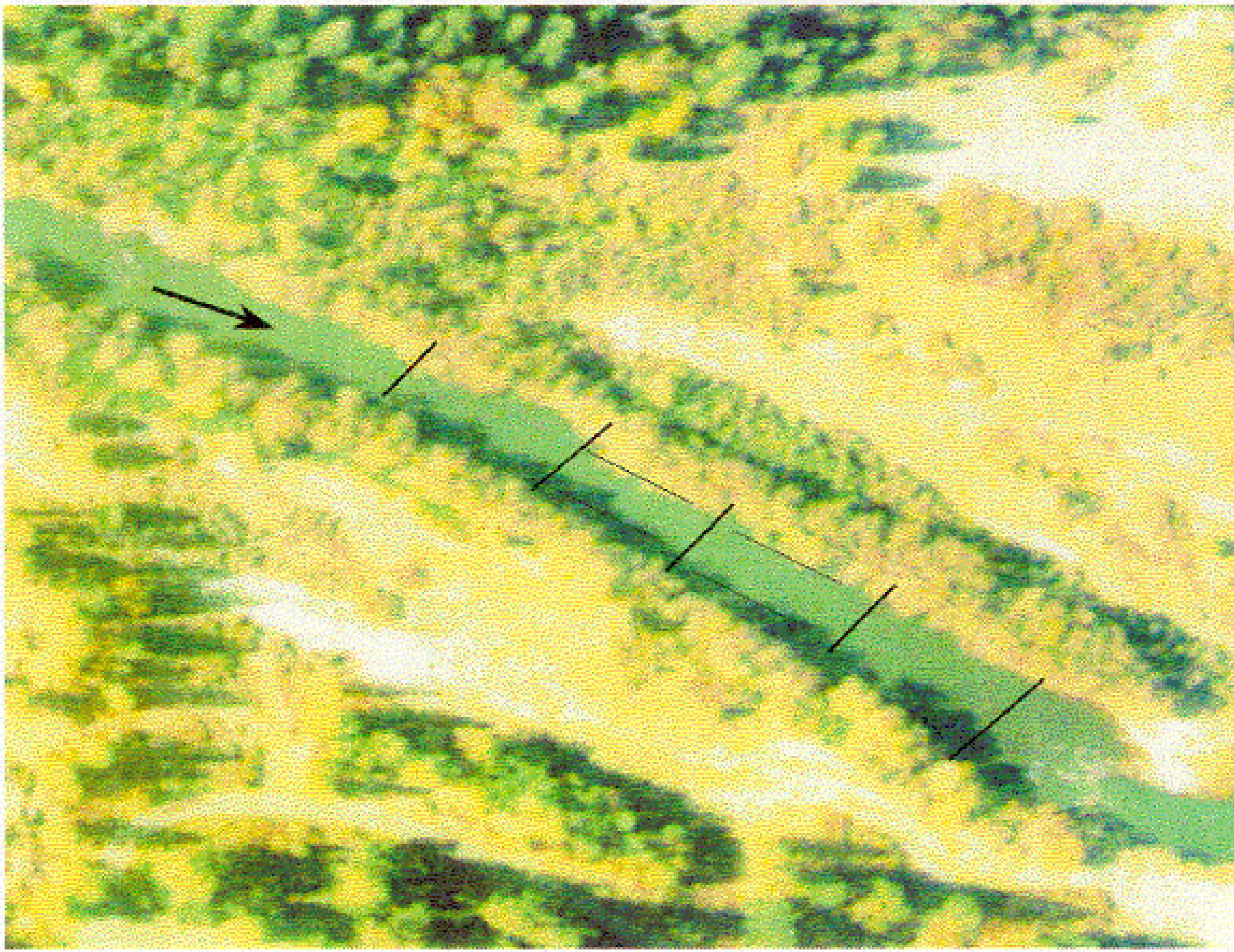


Fig. 5. Douglas City control site on the Trinity River, CA. Thin lines show hydraulic transect locations. Dashed lines indicate fish sampling lane locations. Arrow shows flow direction. Discharge is approximately 13.8 m^3/s. Note campground at bottom of photo.

Fig. 6. Douglas City restoration site on the Trinity River, CA. Thin lines show hydraulic transect locations. Dashed lines indicate locations of fish sampling lanes. Arrow shows flow direction. Flow is approximately 12 m^3/s.

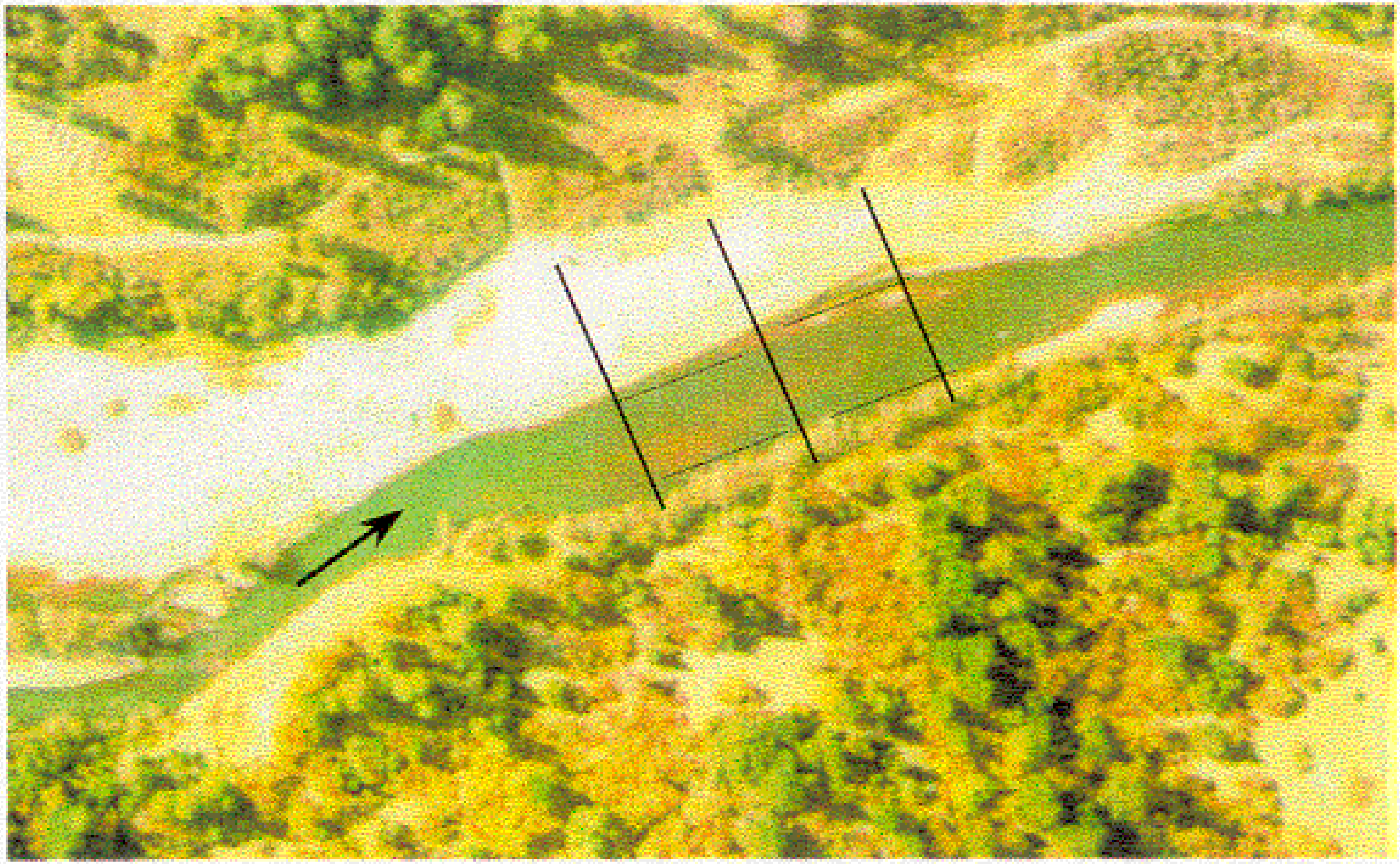


Fig. 7. Bell Gulch restoration site on the Trinity River, CA. Thin lines show hydraulic transect locations. Dashed lines show general location of fish sampling lanes. Arrow indicates flow direction. Discharge is approximately 13.8 m^3/s.

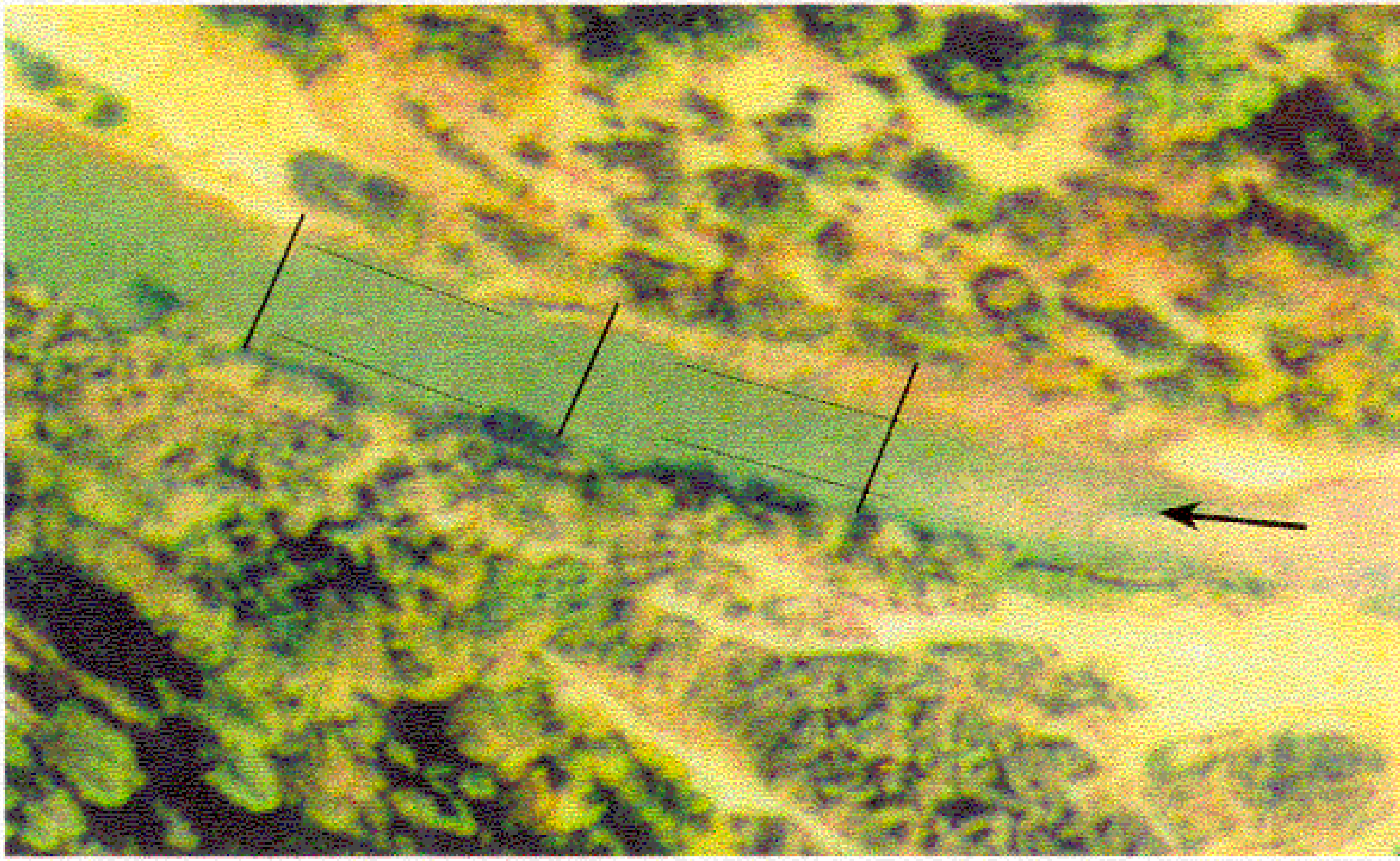


Fig. 8. Bell Gulch control site on the Trinity River, CA. Thin lines show hydraulic transect locations. Dashed lines indicated general location of fish sampling lanes. Arrow shows flow direction. Discharge is approximately 13.8 m^3/s.

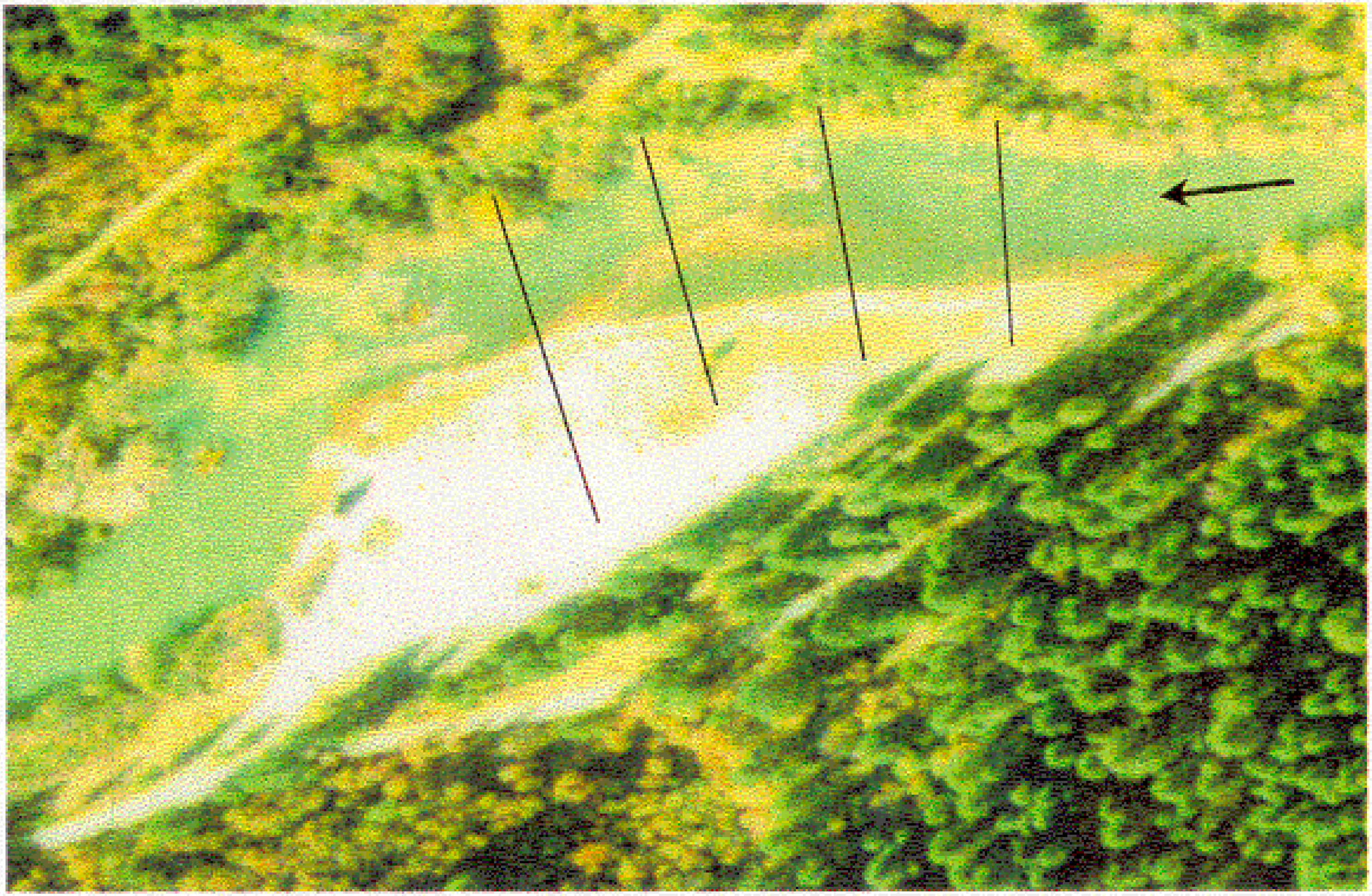


Fig. 9. Steel Bridge restoration site on the Trinity River, CA. Thin lines show approximate locations of hydraulic transects. Arrow indicated flow direction.

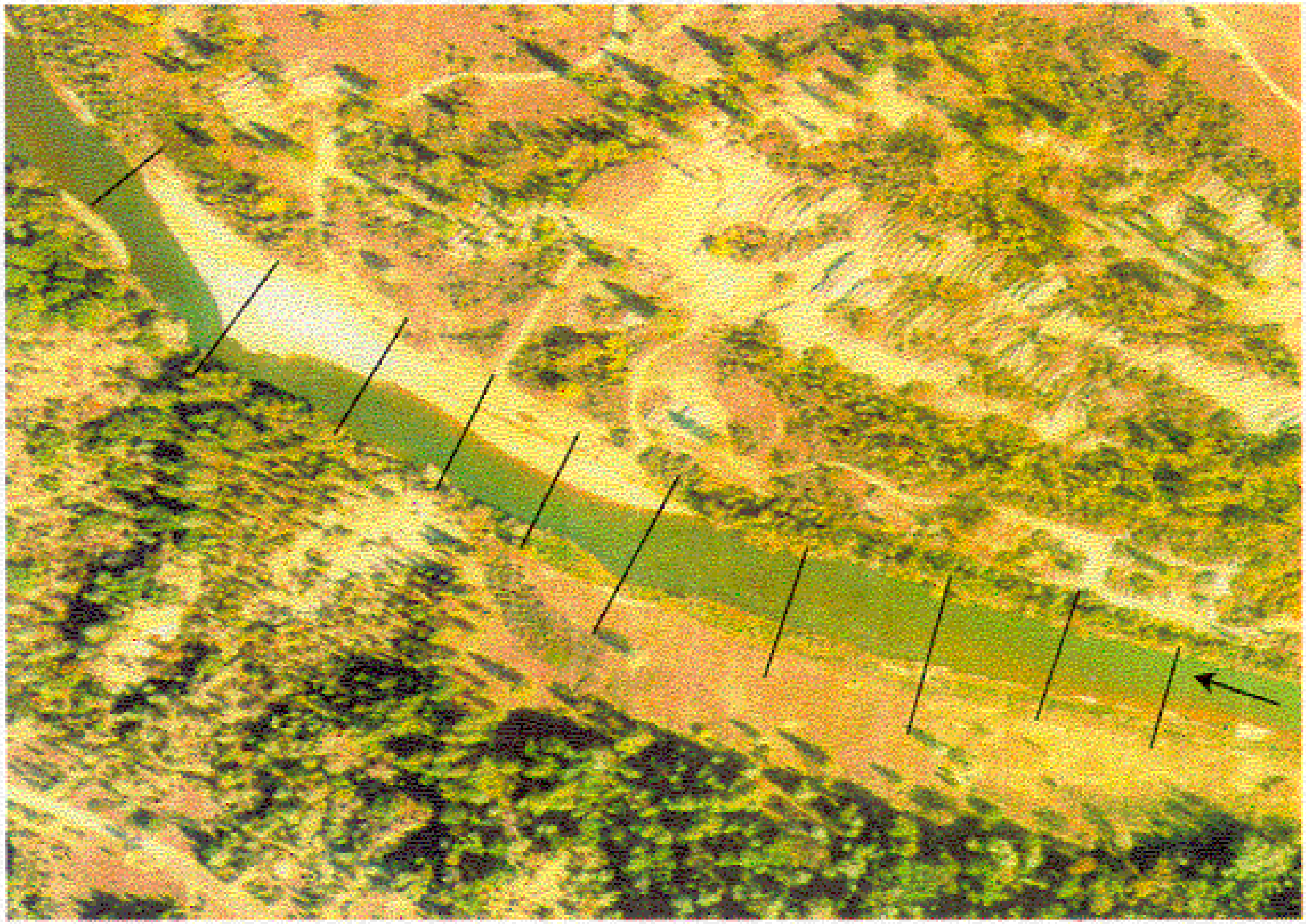


Fig. 10. Deep Gulch and Sheridan restoration sites on the Trinity River, CA. Thin lines indicate approximate locations of hydraulic transects. Arrow shows flow direction. Deep Gulch is in lower right. Sheridan is upper left. Note both sites share 1 transect.

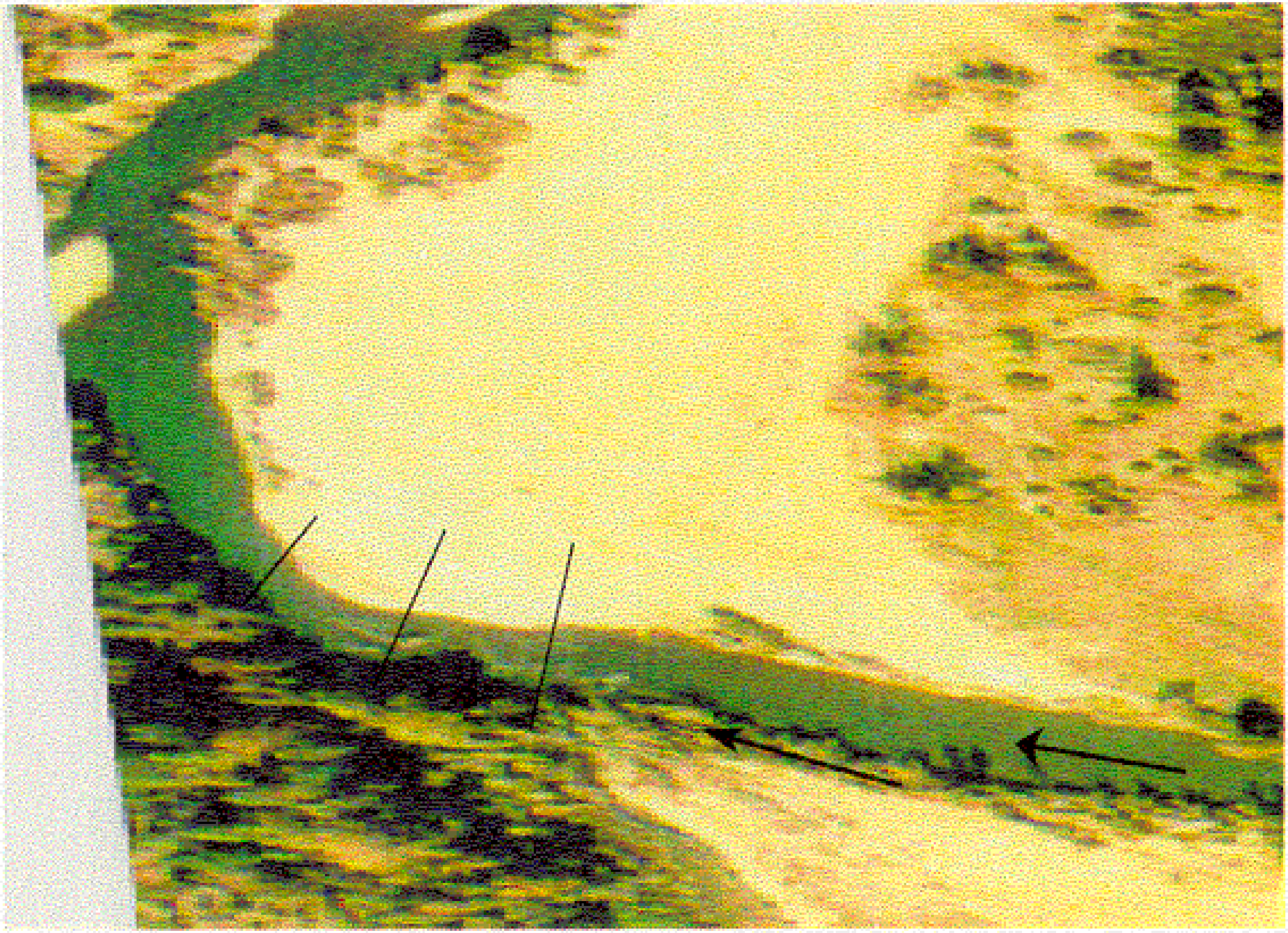


Fig. 11. Junction City "natural" site on the Trinity River, CA. Thin lines show transect locations. Arrow indicates flow direction.

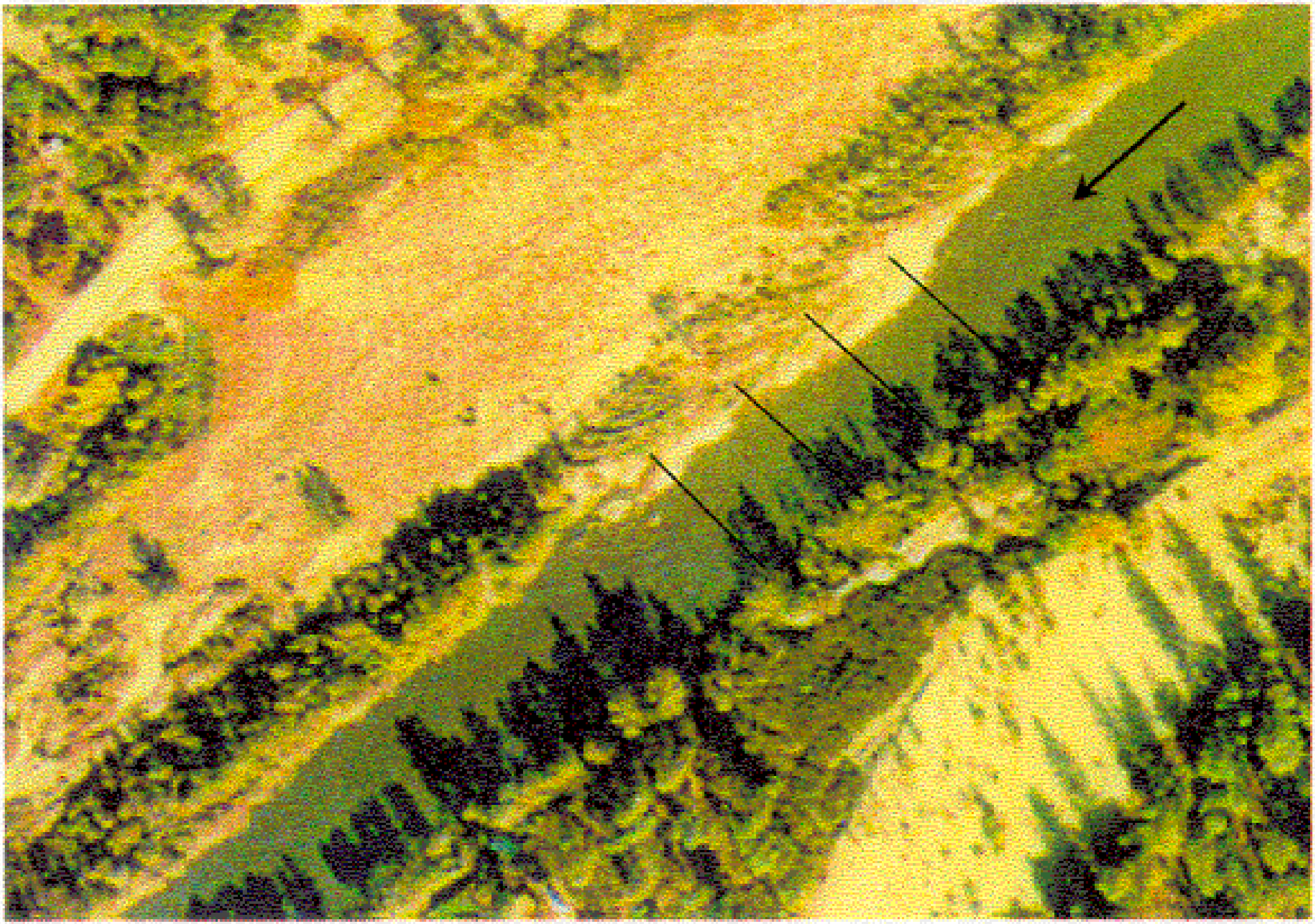


Fig. 12. Jim Smith restoration site on the Trinity River, CA. Thin lines represent hydraulic transect locations. Arrow indicates flow direction.

Fig. 13. Pear Tree restoration site on the Trinity River, CA.

APPENDIX B

Habitat Use Table.

Table 20.- Species and life stage habitat type use (presence or absence) of microhabitat types in the Trinity River, California. Numbers are average persent use from elctrofishing for of each habitat type. The X's represent species and life stage we expect to be found in these habitats.

	Bank Formed Eddy BAKEDDY	Bank Formed Edge Water BAKEW	Bank Point Back Water BAKPBW	Bank Point Eddy BAKPEDDY	Bank Point Edge Water BAKPEW	Boulder Formed Eddy BEEDDY	Boulder Formed Edge Water BFEW	Boulder Pocket BP	Boulder Formed Edge Water BPEW	Bed Rock Formed Edge Water BRFEW	Bed Rock Pocket BRP	Bed Rock Point Back Water BRPBW	Bed Rock Point Eddy BRPEDDY	Bed Rock Point Edge Water BRPEW	Cobble Bar Under Water CBUW	Cobble Formed Edge Water CFEW
Chinook Fry	2.9	3.2	10.8	1.0	7.3	X	4.2	6.9	9.5	1.0	X	X X	1.1	7.6	0.3	1.3
Chinook Juvenile	X	5.9	34.8	7.6	8.1	X	2.9	1.7	X	X	X		X	X	X	3.2
Chinook Adult Holding															X	
Chinook Spawning																
Coho Juvenile	X	8.1	0.0	X	X	X	0.0	X	0.0	0.0	0.0	0.0	X	0.0	X	X
Coho Fry	X	X	X	X	X	X	X		X			X	X			
Coho Adult Holding																
Coho Spawning															X	
Steelhead Juveniles	X	9.1	0.0	X	2.9	X	X	X	7.6	13.7	X	0.0	X	3.1	8.8	0.0
Steelhead Fry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Steelhead Adult Holding																
Steelhead Spawnig															X	
Brown Trout Fry	X	X	0.0	X	20.1	X	X	0.0	X	X	0.0	0.0	10.6	X	2.3	X
Brown Trout Juvenile	X	X		X	X	X	X	X	X	0.0	X		X	X	0.0	0.0
Brown Trout Adult Feeding																
Brown Trout Spawning															X	
Lamprey Ammocetes	X	1.2	X	0.3	7.2	X	0.0	0.0	0.0	X	0.0	X	2.3	3.0		0.0
Lamprey Spawning																
Dace	16.4	2.9	0.0	X	0.0		5.9	0.0	0.0	0.0	0.0		X	0.0	10.0	25.2
Sucker Juveniles	0.0	48.3	0.0	0.0	34.5		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Sucker Adults																
Stickle Back	0.0	2.5	44.2	0.0	3.3		17.0	0.0	0.0	0.0	0.0	X	0.0	0.0	0.0	0.0
Green Sunfish												X				50.0

	Cobble Point Back Water CPBW	Cobble Point Eddy CPEDDY	Cobble Point Edge Water CPEW	Flow Substrate Transition FST	Grass Clump Back Water GCBW	Grass Clump Eddy EDDY	Grass Clump Edge Water GCEW	Grass Clump Pocket GCP	Log Formed Back Water LFBW	Log Formed Eddy LFEDDY	Log Formed Edge Water LFEW	Log Pocket LP	Mid Channel Open Water <0.5 MCOW1	Mid Channel Open Water 0.6 1 MCOW3	Mid Channel Open Water > 2.0 MCOW4	Mini-Side Channel MSC	Off Channel Area OCA
Chinook Fry	X	X	6.1	1.3	X	X	5.3	4.1	X	2.0	2.4	X	2.6	X		7.9	2.8
Chinook Juvenile	X	X	3.4	X	X	X	X	X	X	X	X	X	0.9	X		12.4	X
Chinook Adult Holding				X										X	X		
Chinook Spawning														X	X		
Coho Juvenile	0.0		0.0	0.0	0.0	X	7.0	X	X	X	16.6	X	0.0			X	0.0
Coho Fry					X	X	X	X	X	X	X					X	
Coho Adult Holding													X	X	X		
Coho Spawning				X									X	X	X		
Steelhead Juveniles	0.0	X	X	7.7	0.0	X	0.0	4.7	X	5.0	4.8	2.2	0.0	X	X	1.2	0.0
Steelhead Fry	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
Steelhead Adult Holding													X	X	X		X
Steelhead Spawnig				x									X	X	X		
Brown Trout Fry	32.8	X	2.0	0.0	0.0	X	24.5	X	X	X	X	0.0	3.0			4.6	X
Brown Trout Juvenile	0.0	X	0.0	0.0		X	X	X	X	X	X	X	0.0			X	
Brown Trout Adult Feeding									X	X			X				
Brown Trout Spawning													X	X	X		
Lamprey Ammocetes	0.0	X	1.1	0.0	X	X	X	0.0	X	4.8	1.9	24.9	0.0	X	X	3.1	X
Lamprey Spawning				X									X	X	X		
Dace	0.0	X	1.1	X	0.0	X	X	0.0	0.0	0.0	0.0	0.0	30.6	X		7.8	0.0
Sucker Juveniles		X	17.2	X	0.0				0.0	0.0	0.0	0.0	X	X		0.0	
Sucker Adults													X	X	X		
Stickle Back	0.0		3.9	0.0	X	X	5.3	15.5	X	0.0	3.3	0.0	0.0			5.0	0.0
Green Sunfish																	50.0

Table 20- Continuted.

	Rootwad Formed Eddy	Rootwad Formed Edge Water	Rootwac Pocket	Under Cut Bank	
	RWFEDDY	RWFEW	RWP	UB	Total # Individuals
Chinook Fry	1.0	3.1	0.7	3.7	437.0
Chinook Juvenile	12.9	6.2	X	X	58.0
Chinook Adult Holding					X
Chinook Spawning					X
Coho Juvenile	6.0	21.3	18.2	X	26.0
Coho Fry	X	X	X	X	X
Coho Adult Holding					X
Coho Spawning					X
Steelhead Juveniles	7.6	3.1	5.4	13.3	69.0
Steelhead Fry	X	X	X	X	X
Steelhead Adult Holding					X
Steelhead Spawnig					X
Brown Trout Fry	X	X	X	X	15.0
Brown Trout Juvenile	X	X	X	X	X
Brown Trout Adult Feeding					X
Brown Trout Spawning					X
Lamprey Ammocetes	2.3	17.2	12.3	17.9	72.0
Lamprey Spawning					X
Dace	0.0	0.0	0.0	0.0	30.0
Sucker Juveniles	0.0	X	0.0	X	5.0
Sucker Adults					X
Stickle Back	0.0	0.0	0.0	0.0	21.0
Green Sunfish					2.0